Instrument Division

VARIAN associates

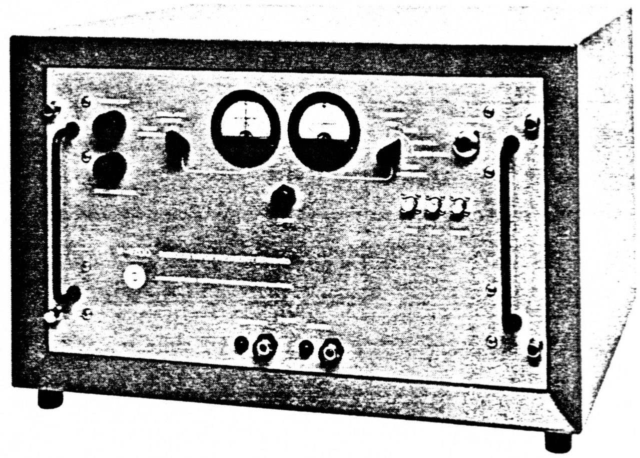
RUBIDIUM VAPOR FREQUENCY STANDARD

V-4700A

DATA & PRICE SHEET

The natural invariant physical reference which makes possible the degree of accuracy and stability achieved by the Varian Model V-4700A Rubidium Vapor Frequency Standard is the Rb^{87} ground state hyperfine transition of 6834.69 . . . mc. The Rubidium Vapor Frequency Standard utilizes the principles of optical pumping and transmission monitoring to couple the output frequency to this physical atomic reference.

Optical pumping selectively removes rubidium atoms from the optically opaque lower hyperfine ground state and transfers them to the optically transparent upper hyperfine ground state, resulting in an overpopulation of the transparent state. By subjecting the atoms in the overpopulated state to a microwave magnetic field whose frequency corresponds to the hyperfine separation, transitions are induced back to the opaque optical state from the transparent state. This causes a change in intensity of rubidium light transmitted through the vapor and serves as an indication of coincidence of the rubidium hyperfine frequency and the frequency of the microwave field. Changes in intensity of transmitted light are converted by a photocell into an electrical signal which, by means of an electronic integrating servo, is used to stabilize the five megacycle crystal oscillator from which the microwave field is derived.



Rubidium Vapor Frequency Standard

GENERAL SPECIFICATIONS

Output Frequencies	5 mc, 1 mc and 100 kc, simultaneously. Other frequencies available on special order.
Output Level	5 mc and 1 mc: 1v rms into 50 ohms. 100 kc: 1v rms into 50 ohms, or minimum 3v into approximately 15,000 ohms, selected by internal switch.
Long-Term Stability	5×10^{-11} over any 1-year period (Standard Deviation).
Short-Term Stability	1×10^{-11} over a one-second averaging time (Standard Deviation).
Spectral Purity	Less than 2 cps bandwidth at 24 kmc when derived from 5 mc output.
Environmental Stability	Above long- and short-term stability specifications will be maintained over the following conditions: Temperature: 15° to 35°C Humidity: 0 to 95% Input voltage: ±15% of nominal Load: Open to short circuit
Accuracy and Frequency	Instrument is calibrated to any customer-specified time scale within 4×10^{-8} of A.1, to an accuracy of $\pm 1 \times 10^{-10}$ relative to the U.S. Frequency Standard.
Fine Tuning Precision	Magnetic field tuning allows adjustment of frequency over a range of $+5 \times 10^{-9}$ to a setting precision of 1×10^{-11}.
Stabilization Time	Instrument accuracy is $\pm 1 \times 10^{-10}$ after a two-hour warmup. Turn-off/turn-on repeatability $\pm 2 \times 10^{-11}$ after 12-hour warmup.
Crystal Oscillator Locking System	Crystal oscillator frequency is locked to the Rb^{87} hyperfine frequency by an entirely electronic integrating servo having a d-c gain of approximately 10^8 and a unity gain point of 70 cps.
Alarm Indicator	Front panel alarm light indicates visually that the output frequency is locked to the hyperfine transition frequency. Rear terminals connected to relay contacts provide for remote alarm systems.
Input Requirements	28v dc nominal, @ 2a.
Packaging	The frequency standard is housed in a cabinet accommodating a 19-inch panel. Cabinet dimensions are 21-7/16 inches wide x 12⅞ inches high x 18 inches deep (2.9 cu. ft.). Total weight is approximately 95 pounds.

PRICE: $15,900 f.o.b. Palo Alto, California. Terms: 30 days net.

DELIVERY: 90 days from receipt of order.
(Price and delivery subject to change without notice)

ORDERING INFORMATION: Please specify time scale when ordering.

DESCRIPTION

A block diagram of the Alkali Vapor Frequency Standard System is shown below. The Rb^{87} vapor, whose hyperfine transition frequency is being monitored, is contained in a glass gas cell which in turn is housed in a microwave cavity. In order to obtain narrow spectral lines, a noble gas buffer is used to reduce the number of disorienting collisions of the rubidium atoms with the walls of the gas cell. In addition to giving narrow lines, these buffer gases cause a shift in the hyperfine frequency from its value of 6,834,682,614 cps. This pressure shift is utilized to simplify the problem of synthesizing the integral megacycle output frequency.

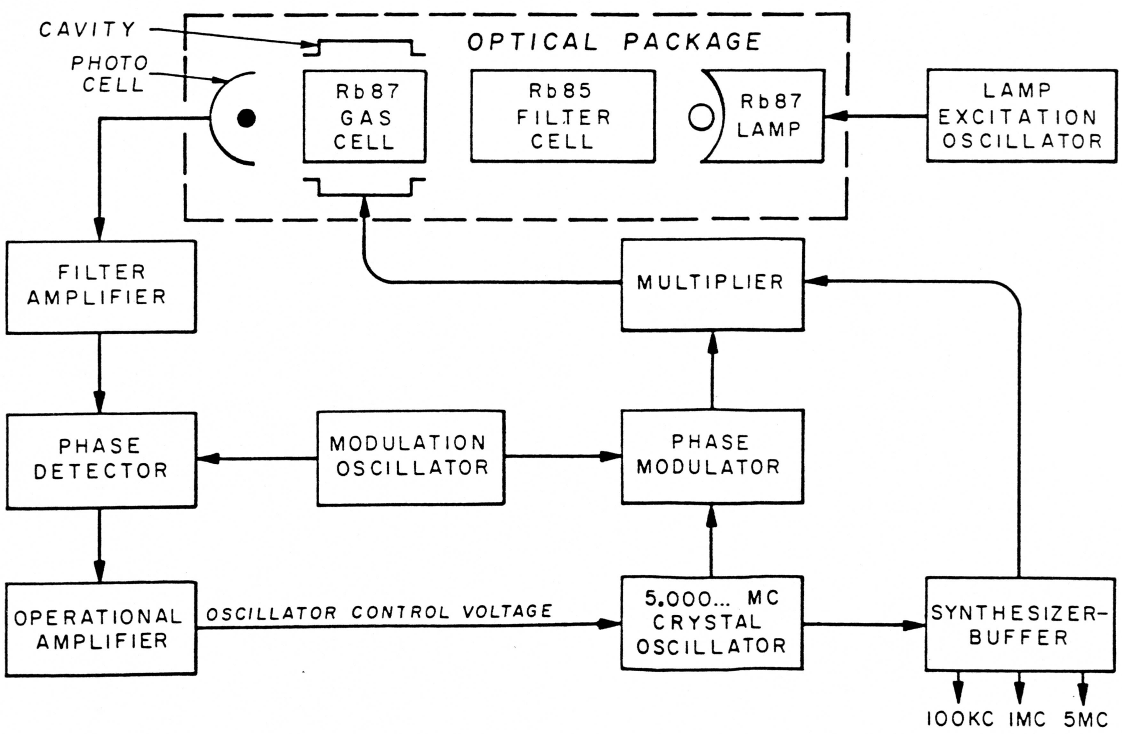
An important feature of the Rubidium Vapor Frequency Standard is the fact that the gas cell may be filled to give an integral megacycle output frequency on any preselected time scale. For example, the gas cell could be filled on the A.1 time scale for which the cesium hyperfine frequency is 9,192,631,770 cps, or on the current standard frequency broadcast offset of -130×10^{-10} compared to A.1, or on the time scale used with the commercial cesium beam standard in which the cesium frequency under operating conditions is chosen to be 9,192,631,840 cps. More than one gas cell, each with its own pretuned cavity, may be supplied with the instrument, if it is desired to change from one time scale to another.

The resonant cavity which surrounds the gas cell is tuned to the hyperfine frequency and is excited by a phase modulated microwave signal. When the frequency of the resulting microwave magnetic field corresponds to the hyperfine frequency, transitions back to the optically opaque state are induced in the rubidium vapor resulting in a reduction of transmitted light.

The Varian Rubidium Vapor Frequency Standard contains two principal electronic subsystems. These are the totally electronic integrating servo for control of the local crystal oscillator, and the electronic frequency multiplying and synthesizing networks for multiplication of the local oscillator frequency up to the hyperfine frequency and for synthesis of the integral megacycle and other outputs.

A silicon solar cell is used to sense the level of light transmitted through the gas cell. The output of this solar cell contains a small a-c component which depends upon the relation of the frequency driving the cavity to the hyperfine frequency of the rubidium vapor. If the two frequencies are coincident, the transmitted light will be modulated at only second and higher harmonics of the modulation frequency. If the frequency of the microwave field is either higher or lower than the hyperfine frequency, a fundamental component of the modulation frequency will appear at the output. The phase of this component relative to the modulation frequency will depend upon the magnitude and sign of excursion from the hyperfine frequency.

In the phase detector, the phase of the optical output signal is compared with the phase of the modulation signal and the error signal is applied as a continuous correction to the five-megacycle crystal oscillator. This five-megacycle oscillator serves as the basic source for microwave energy to excite the cavity as well as a source for the various output frequencies. A frequency of 6834-13/19 mc is derived from the oscillator using a combination of multiplication and division, and the proper degree of buffer pressure shift is employed in the gas cell to bring the hyperfine frequency into coincidence with this synthesized frequency. Regenerative division and subsequent buffering provide the appropriate integral megacycle and 100-kc outputs.



Rubidium Vapor Frequency Standard Block Diagram

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Instruction Manual

T.O. FILE

MODEL V-4700A

RUBIDIUM VAPOR FREQUENCY STANDARD
PHILCO CORPORATION
Vandenberg Air Force Base
Serial No. 14

September, 1962

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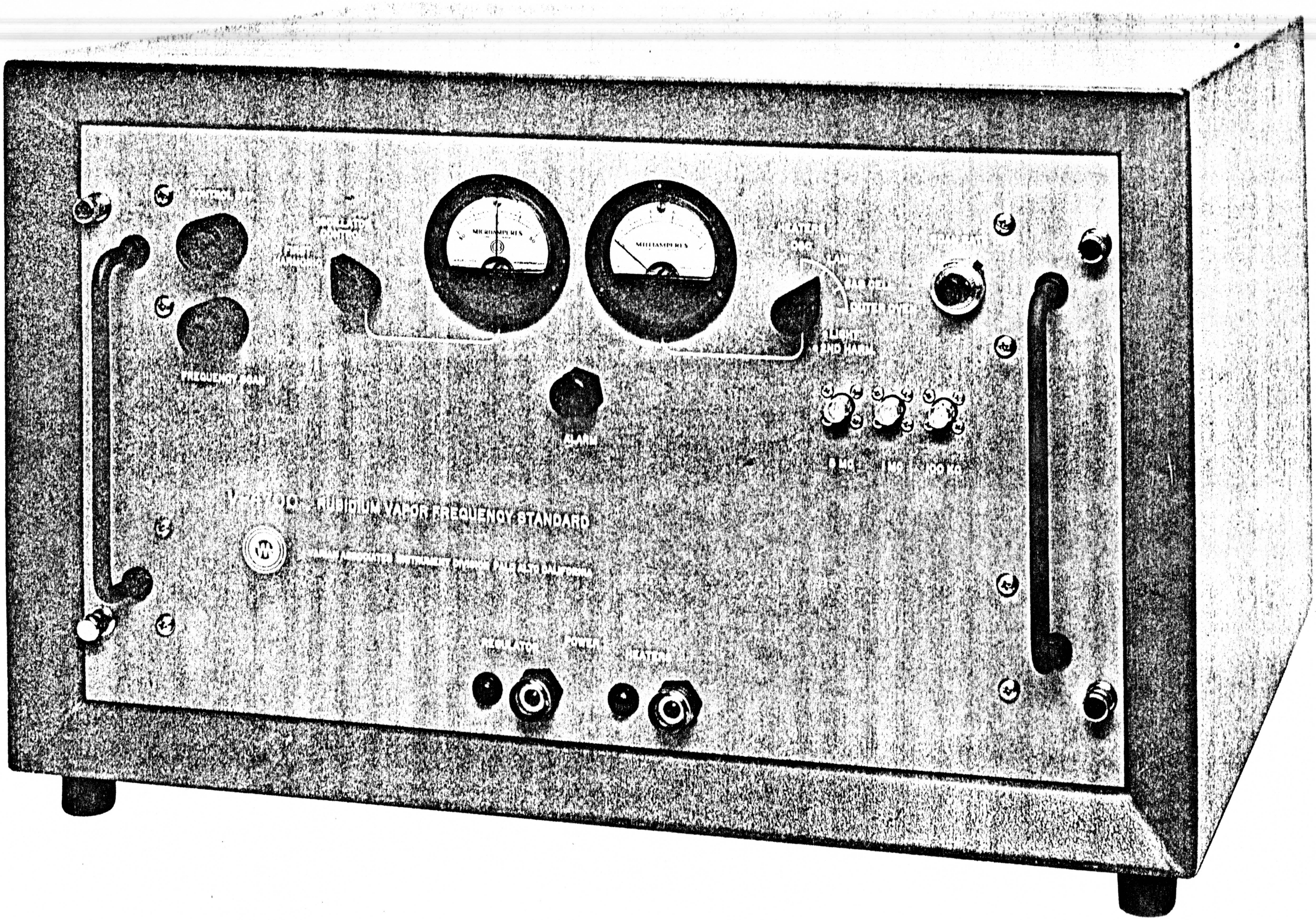


FIGURE 1-1. FRONT PANEL, V-4700A RUBIDIUM VAPOR FREQUENCY STANDARD

MODEL V-4700A RUBIDIUM VAPOR FREQUENCY STANDARD
INSTRUCTION MANUAL

1.0 INTRODUCTION

1.1 PURPOSE

The Varian Model V-4700A Rubidium Vapor Frequency Standard is an instrument designed to provide highly stable frequency outputs at 5 mc, 1 mc, and 100 kc.

1.2 GENERAL DESCRIPTION

This instrument utilizes the principles of optical pumping and transmission monitoring. By means of these techniques, the 5 mc crystal oscillator is stabilized against the invariant field independent hyperfine transition of rubidium 87. The instrument is designed for continuous operation.

Figure 1-1 shows a front view of the V-4700A Rubidium Vapor Frequency Standard. Front panel controls and metering are provided for locking the oscillator to the atomic transition and monitoring the operation of the instrument. Rear control and monitoring points are provided for initial adjustment of the instrument.

1.3 GENERAL SPECIFICATIONS

Output Frequencies	5 mc, 1 mc, and 100 kc simultaneously. Additional frequencies are available upon special request.
Output Level	5 mc and 1 mc: 1v rms into 50 ohms. 100 kc: 1v rms into 50 ohms, or minimum 3v into approximately 15,000 ohms, selected by internal switch.
Long Term Stability	5×10^{-11} in any 1-year period (Standard Deviation).

1.3 GENERAL SPECIFICATIONS (Con't)

Short Term Stability	1×10^{-11} for a one-second averaging time (Standard Deviation)
Spectral Purity	Less than 2 cps bandwidth at 24 kmc when derived from 5 mc output.
Environmental Stability	Above long- and short-term stability specifications are maintained over the following conditions: Humidity: 0 to 95% Temperature: 15° to 35° C. Input Voltage: ± 15% of nominal Load: Open to short circuit
Accuracy and Frequency	Instrument is calibrated to any customer-specified time scale within 4×10^{-8} of A.1, to an accuracy of $\pm 1 \times 10^{-10}$ relative to the U. S. Frequency Standard.
Fine Tuning Precision	Magnetic field tuning allows adjustment of frequency over a range of $+5 \times 10^{-9}$ to a setting precision of 1×10^{-11}.
Stabilization Time	Instrument accuracy is $\pm 1 \times 10^{-10}$ after a two-hour warmup. Turn-off/turn-on repeatability $\pm 2 \times 10^{-11}$ after 12-hour warmup.
Crystal Oscillator Locking System	Crystal oscillator frequency is locked to the RB^{87} hyperfine frequency by an entirely electronic integrating servo having a d-c gain of approximately 10^8 and a unity gain point of 70 cps.
Alarm Indicator	Front panel alarm light indicates visually that the output frequency is locked to the hyperfine transition frequency. Rear terminals connected to relay contacts provide for remote alarm systems.
Input Requirements	28v dc nominal, at 2a.
Packaging	The frequency standard is housed in a cabinet accommodating a 19-inch panel. Cabinet dimensions are 21-7/16 inches wide x 12-7/8 inches deep (2.9 cu. ft.). Total weight is approximately 95 pounds.

1.4 V-4760 STANDBY POWER SUPPLY

1.4.1 Purpose

The Varian V-4760 Standby Power Supply, shown in Figure 1-2, is specifically intended for use with the Varian V-4700A Rubidium Vapor Frequency Standard. It is designed to operate with standby batteries floating across the output in order to provide continuous d-c power in the event of line failure. A 20 cell nickel cadmium battery is recommended. Cell size should be chosen to provide 2.5 amps for the required standby period. The battery is to be provided by the customer.

1.4.2 General Specifications

Output Voltage	28 volts dc, during normal operation. 31 volts dc, during charging cycle.
Output Current	5 amps regulated; short circuit current passively limited to 10 amps.
Input Power	115 volts, 60 cps; 50 cps model available upon special request. Approximately 500 watts maximum input power.
Front Panel Metering	D-c output voltage and battery charge/discharge current.
Front Panel Controls	Input power circuitbreaker with 5-amp capacity. Battery charge/discharge circuitbreaker with 10-amp capacity. Battery over-voltage charging timer.
Packaging	Power supply is normally housed in a cabinet but can be removed for 19-inch rack mounting. Cabinet dimensions are 21-7/16 inches wide x 7-3/4 inches high x 18 inches deep (1.8 cu. ft.). Total weight is approximately 53 pounds. Rack mounting height is 5-1/4".

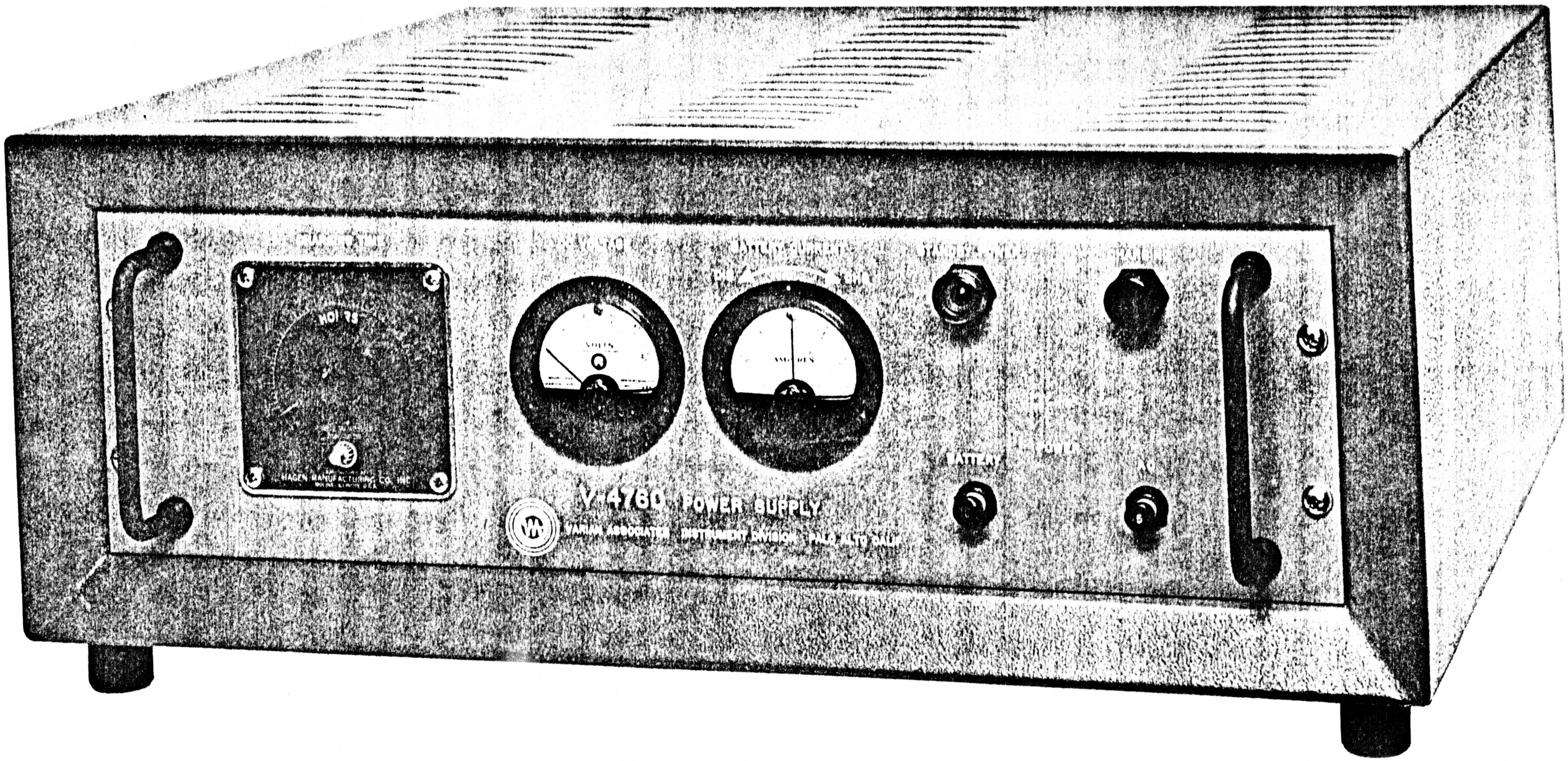


FIGURE 1-2. FRONT PANEL, V-4760 POWER SUPPLY

2.0 THEORY OF OPERATION

2.1 PRINCIPLES OF OPTICAL PUMPING AND TRANSMISSION MONITORING

The instrument uses optical pumping and transmission monitoring to detect the atomic hyperfine transition of Rb^{87}. This hyperfine splitting arises from the interaction between the electron spin, $S = 1/2$, and the Rb^{87} nuclear spin, $I = 3/2$, and is in free space at a frequency of 6,834,682,614 cps.

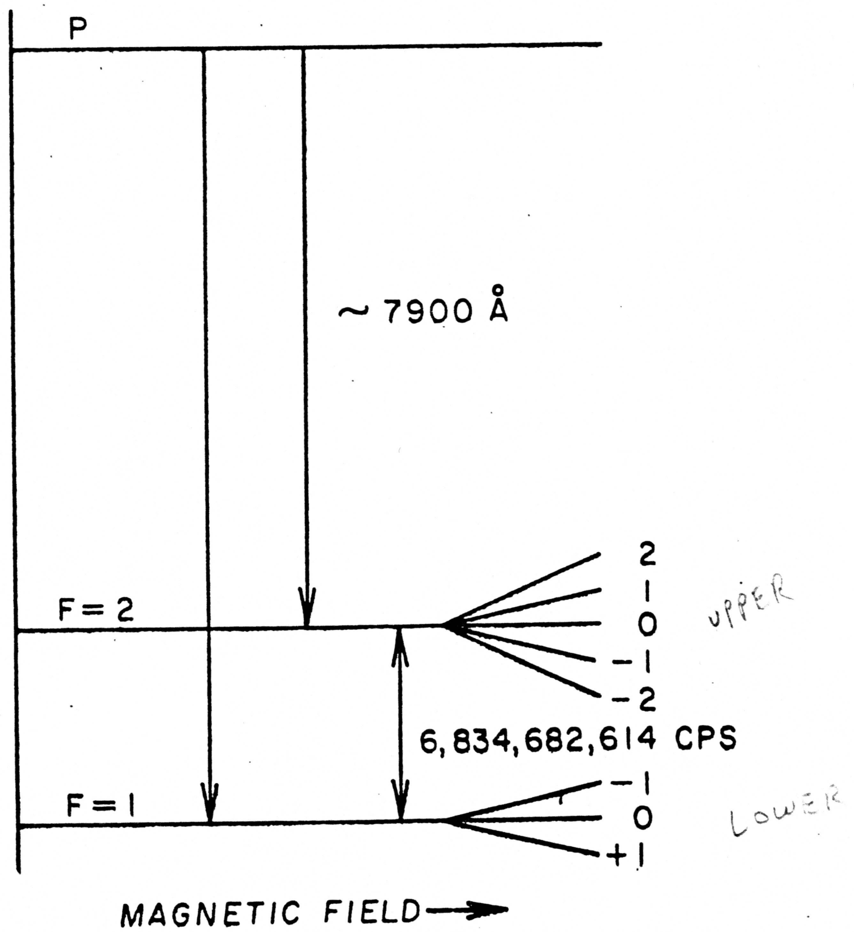


FIGURE 2-1

The first excited states of the Rb^{87} atom are P 1/2 and P 3/2, at wave lengths 7947 Å and 7800 Å, respectively, above the ground state.

Figure 2-1 shows a simplified Rb^{87} energy level diagram, in which only one of the P-states is considered and P-state hyperfine spliting is neglected. The upper hyperfine level, characterized by $F=2$, is split under the application of a magnetic field into the five levels m_F 2, 1, 0, -1, -2; the lower hyperfine level, characterized by $F=1$, is similarly split into the three levels m_F -1, 0, 1. The transition from the $F=2$, $m_F=0$ level to the $F=1$, $m_F=0$ level is virtually independent of magnetic field and is the one used to stabilize the oscillator frequency. This is called the field independent or zero-zero transition.

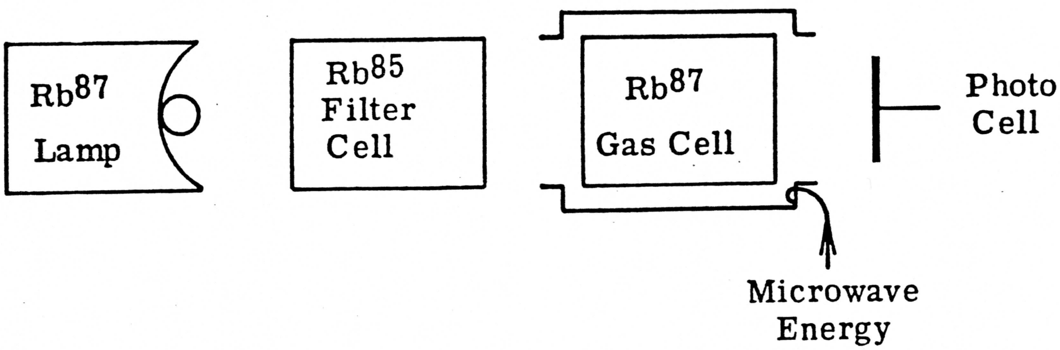


FIGURE 2-2

Figure 2-2 gives a block diagram of the optical system. In terms of Figure 2-1, the Rb^{87} lamp emits spectral radiation of approximately 7900 Å wavelength from the P-state to each of the ground state hyperfine levels, $F=1$ and $F=2$. If the Rb^{87} atoms in the gas cell are irradiated by Rb^{87} light which has the lower energy hyperfine component removed, optical transitions will occur only between the lower hyperfine level ($F=1$) and the excited P-state. Once in the P-state atoms can decay with equal probability to any one of the eight ground state sub-levels. Those which decay to one of the lower energy hyperfine sub-levels

will again be pumped to the excited state; those which decay to the upper hyperfine sub-levels will be unaffected by the light since spectral components which can cause transition from this level have been filtered out. The result is a transfer of population from the optically opaque lower hyperfine level to the optically transparent upper hyperfine level.

The lower energy hyperfine component is removed from the light by a rubidium 85($I = 5/2$) filter cell between the lamp and gas cell. This cell contains Rb^{85} vapor in a carrier gas of a few cm neon, argon, or krypton. The splitting between hyperfine components of the Rb^{85} absorption lines is about half that of Rb^{87}. In addition, because of the different nuclear spin the lower energy Rb^{85} hyperfine component lies considerably closer to the lower energy Rb^{87} hyperfine component than does the higher energy Rb^{85} component to the higher energy Rb^{87} component. The net result is that with carrier gas pressure broadening the lower energy Rb^{85} hyperfine absorption component overlaps the corresponding Rb^{87} emission line and selectively filters it from the light incident on the gas cell. These effects are illustrated in Figure 2-3

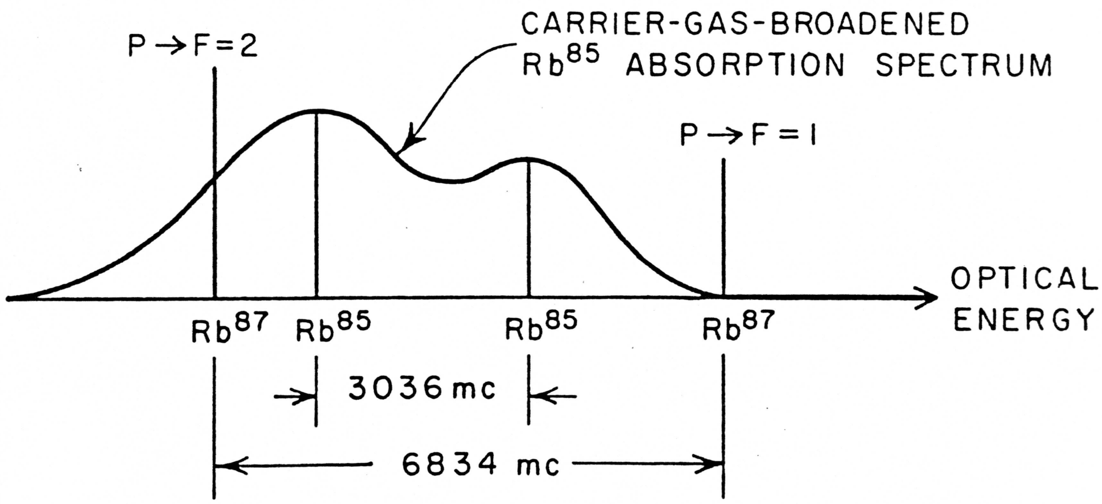


FIGURE 2-3

A microwave magnetic field at the hyperfine frequency will induce transitions between the optically transparent F 2, m_F 0 level, and the optically aborbing F 1, m_F 0 level, and a decrease in light intensity will be noted on the photocell monitoring the transmitted light beam. The signal from the photocell is used to stabilize the oscillator generating the microwave frequency.

To obtain narrow resonance lines, it is necessary that the frequency of disorienting collisions of the rubidium atoms with the walls of the gas cell be reduced to a low level. This is done by use of a buffer gas of 55% neon - 45% argon at approximately 8 mm pressure. In addition to giving narrow lines the buffer gas causes a shift in hyperfine frequency from its free space value of 6,834,682,614 cps. Advantage is made of this shift to simplify the problem of synthesizing the hyperfine frequency from the 5 mc oscillator. The hyperfine frequency is adjusted to be 6834-13/19 6834.684211 mc on whatever time scale is selected with the instrument; time scales may be changed by a simple change of cavity and gas cell.

While the zero-zero hyperfine frequency has no first order magnetic field dependence, a second order effect given by: $\frac{\delta f}{f} = -0.84 \times 10^{-7} H^2$ (H=gauss) exists. Magnetic field tuning may be used to adjust the frequency upward from zero field and may be used to bring standards into precise phase and frequency synchronization in synchronized time networks. Additionally magnetic field tuning may be used to cover all customarily used time scales with one gas cell. By filling the gas cell -170×10^{-10} relative to A.1, UT_2 for some years in the future, A.1, and the time scale -76×10^{-10} relative to A.1, used with commercial cesium beam frequency standards can all be reached within a tuning range of 2×10^{-8}. To maintain stability against changes in environmental magnetic fields, a triple mu-metal magnetic shield with a shielding factor in excess of 1000 is used; with this shield, a change ambient field of one gauss in the worst direction will give a frequency change of less than 1×10^{-10} at the maximum offset of 2×10^{-8}.

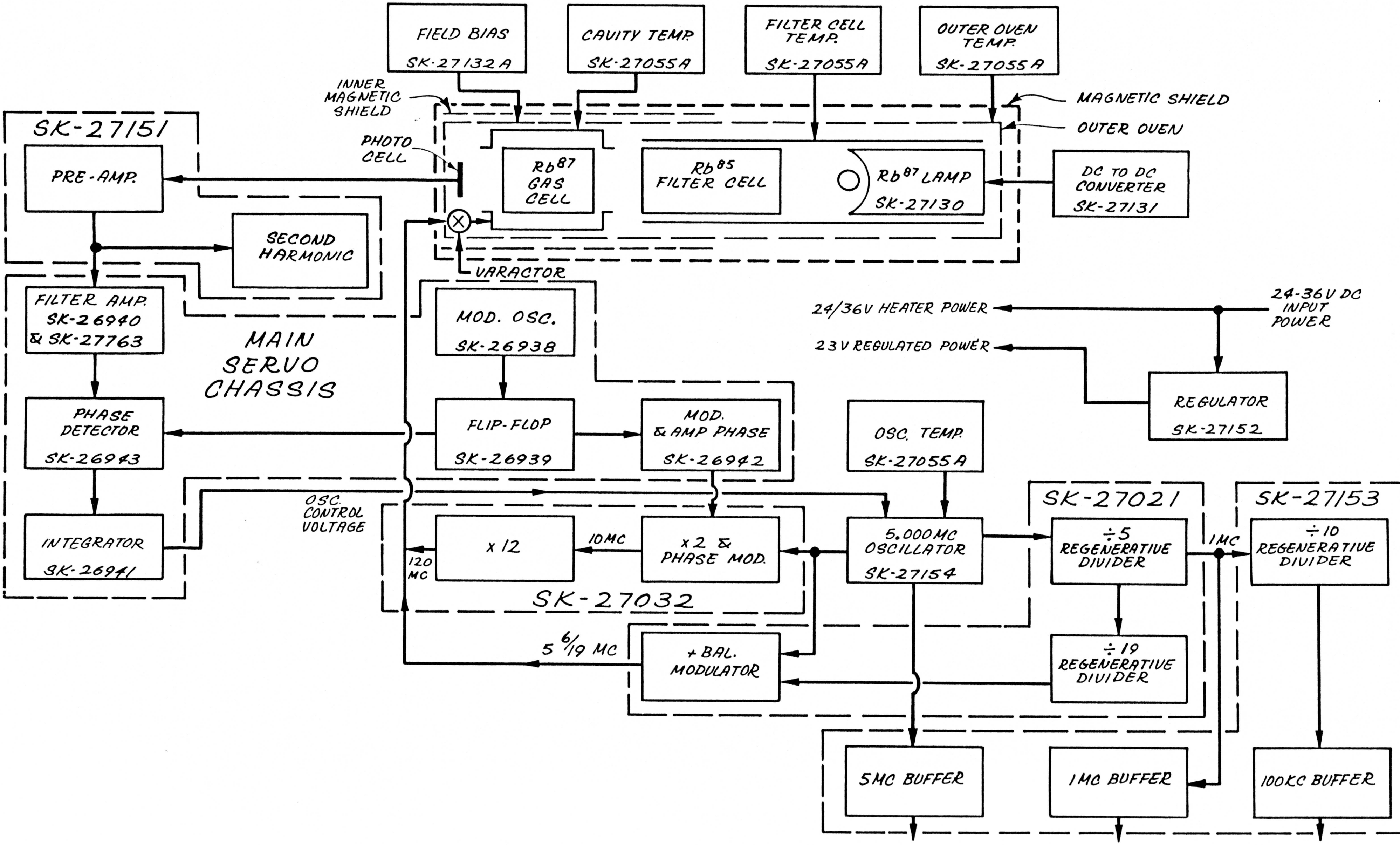


FIGURE 2-4 FREQUENCY STANDARD BLOCK DIAGRAM

2.2 PRINCIPLES OF V-4700A RUBIDIUM VAPOR FREQUENCY STANDARD OPERATION

Figure 2-4 shows a block diagram of V-4700A Rubidium Vapor Frequency Standard. The frequency standard consists of five major subsystems, the RF system, optical system, servo system, regulator, and temperature controllers.

2.2.1 RF System

2.2.1.1 5 mc Oscillator

The oscillator uses a 5 mc fundamental crystal in a circuit designed to give high short-term stability. The MECHANICAL TUNING control on the rear of the instrument provides an oscillator tuning adjustment of approximately 2×10^{-6}. Frequency control is accomplished by application of the oscillator control voltage from the servo system to a Varicap (voltage variable capacitor) in the oscillator circuit. The crystal and oscillator components are controlled in temperature at the crystal turn-over point.

2.2.1.2 Multiplier

The 5 mc output of the oscillator is doubled to 10 mc, phase modulated at a 107 cps rate, and then multiplied to 120 mc. MODULATION AMPLITUDE and MODULATION PHASE adjustments are made by rear servo controls.

2.2.1.3 Synthesizer

Regenerative division is used to divide 5 mc to 1 mc. As part of this divider, 6 mc is also produced. By regenerative division, 6 mc

is divided by 19 to give 6/19 mc. This frequency is then added to 5 mc in a single sideband balanced modulator to give 5-6/19 mc. All regenerative dividers in this instrument are made to start automatically through use of starting oscillators; this oscillator is gated off when the divider operates with an input signal. No output appears unless there is an input signal.

2.2.1.4 Buffer

Regenerative division is used to give 100 kc from the 1 mc input from the synthesizer. In addition, this unit contains the doubler to 10 mc and the buffer amplifiers for the 10 mc, 5 mc, 1 mc, and 100 kc outputs of the instrument.

2.2.1.5 Varactor Multiplier

5-6/19 mc from the synthesizer is brought into the multiplier and put on the same coaxial line with 120 mc. This line then goes to the MA460E varactor diode located in a mount on the end of the microwave cavity. In the diode 120 mc is multiplied by 57 to give a microwave frequency of 6840 mc. The first order lower sideband created by the 5-6/19 mc modulation of the diode then gives a frequency of 6834-13/19 mc; as mentioned previously, this is the frequency to which the gas cell is filled and sealed.

2.2.2 Optical System

The optical system is contained inside a mu-metal shield to shield it from environmental magnetic fields.

2.2.2.1 Lamp and Filter Cell

This assembly contains the lamp and Rb^{85} filter cell in one thermally controlled package. The lamp is driven in an electrodeless RF discharge by a two-tube lamp oscillator operating at a frequency

somewhat in excess of 100 mc. The lamp should operate for over 10,000 hours. A neutral density filter is placed on the end of the lamp-filter cell package to reduce light intensity in the gas cell to the desired value.

2.2.2.2 Cavity, Gas Cell, and Photocell

The cavity, gas cell, and photocell form one thermally controlled unit. The cavity has been factory tuned to the hyperfine frequency. The incident light intensity is adjusted to give an operating line width of approximately 160 cps.

2.2.2.3 Outer Oven, Field Bias, and Inner Magnetic Shield

The thermally controlled lamp-filter cell and cavity gas cell packages are contained in a thermally controlled outer oven, which gives a high degree of thermal shielding to these components. Magnetic field tuning, adjustable through the FIELD BIAS control on the rear of the instrument, provides fine tuning of the unit. An inner mu-metal magnetic shield provides additional shielding to the gas cell.

2.2.3 Servo System

2.2.3.1 Preamplifier

The output of the photo cell goes to a high speed chopper preamplifier designed to minimize excess noise from the silicon solar cell and input transistor. Figure 2-5 shows a resonance signal as seen at the rear scope terminals.

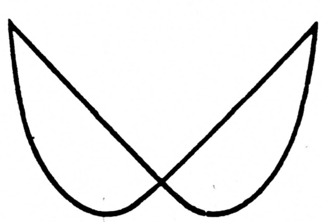


FIGURE 2-5

2.2.3.2 Second Harmonic Circuitry

At resonance the signal from the photocell contains only even harmonics, predominately second harmonic. The second harmonic content of the signal from the photocell is used as an indication of signal strength and that the system is locked. The output of preamplifier is passed through a second harmonic filter and rectified. This rectified 2nd Harmonic output is metered on the front panel; in addition a relay is activated by the second harmonic level. If it drops below some preset level, the ALARM light goes on on the front panel and EXTERNAL ALARM contacts connected to a plug on the rear of the instrument are tripped.

2.2.2.3 Filter Amplifier

A sharp notch filter removes the second harmonic in the signal channel. The signal is further amplified and may be controlled in gain by the AMPLIFIER GAIN control on the rear of the instrument.

2.2.3.4 Modulation Oscillator and Trigger

The basic modulation oscillator operates at 214 cps, which is twice the modulation frequency. A sharp trigger spike is then derived from the output of this oscillator.

2.2.3.5 Flip-Flop

The flip-flop is triggered by these spikes and divides the modulation oscillator frequency to 107 cps. The timing symmetry between the two states of the flip-flop is better than 1×10^{-5}. This precisely timed output is used as the reference to the phase detector.

2.2.3.6 Modulation Amplitude and Phase

The output of the flip-flop is filtered to a sine wave and then controlled by the rear MODULATION AMPLITUDE and MODULATION

PHASE controls before being applied to the phase modulator in the RF multiplying chain. Because of the precise manner in which it is derived the modulating waveform has an even harmonic content smaller than 1×10^{-4}.

2.2.3.7 Phase Detector

A transistor phase detector with low offset error is used to convert error information carried at the modulation frequency to error information about dc. The output of the phase detector may be metered on the FIRST HARMONIC position on the front panel. The phase of the signal to the phase detector may be inverted by the rear PHASE INVERSION switch.

2.2.3.8 Operational Amplifier

The operational amplifier is a very high gain chopper-stabilized d-c amplifier which is used with a feedback capacitor to provide an all-electronic integrator. Other circuitry associated with the operational amplifier is used to shape the gain-frequency characteristics of the frequency control servo loop at frequencies above 1/5 cps. In normal operation the loop gain of the system is unity somewhere between 40 and 60 cps. From here to 1/5 cps, the loop gain is brought up at 12 db/octave to give a loop gain of over 400 at 1 cps. Below 1/5 cps the loop has integral control with loop gain increasing 6 db/octave with decreasing frequency. The total d-c loop gain is in excess of 10^8, which is so large as to be meaningless. The important criterion is drift stability of the phase detector and operation amplifier; typical variations in these should cause frequency errors no greater than 2×10^{-12}. The gain of the operational amplifier feedback loop may be controlled by the INTEGRATOR GAIN control on the rear of the instrument.

2.2.4 Regulator

The power requirements of the V-4700A are 2.5 amps at 24-36 v dc. All circuits except the heaters operate from the output of a 23 v regulator. This isolates these circuits from supply voltage fluctuations as batteries are discharged and charged.

2.2.5 Temperature Controller

The crystal oscillator, lamp-filter cell package, cavity-gas cell, and outer oven all have proportional temperature control. The controllers use a sensing thermistor in a bridge circuit driven by a separate oscillator, an amplifier, and a phase-sensitive detector whose output actuates a power transistor controlling heater current.

2.2.6 V-4760 Standby Power Supply

The power requirements for the V-4760 Standby Power Supply are 117 vac ±10% 60 cycles, at approximately 120 watts. The basic d-c power is supplied by a Sola constant voltage transformer-rectifier combination at 28 vdc or 31 vdc. The unit is designed to be operated with nickel-cadmium or lead-acid standby batteries. The basic power source is passively self-limiting in current at approximately 10 amps and thus has the required characteristics as a battery charger. The normal output voltage from this portion of the power supply is 28 v; the voltage may be raised to 31 v by turning on the CHARGING TIME timer. This overvoltage, which is turned off in the period of time set on the CHARGING TIMER, is used to fully recharge nickel-cadmium batteries. If lead-acid batteries are used, the timer need not be used. If batteries are used they remain floating across the power supply and without switchover will deliver power if 60 cycle power is turned off.

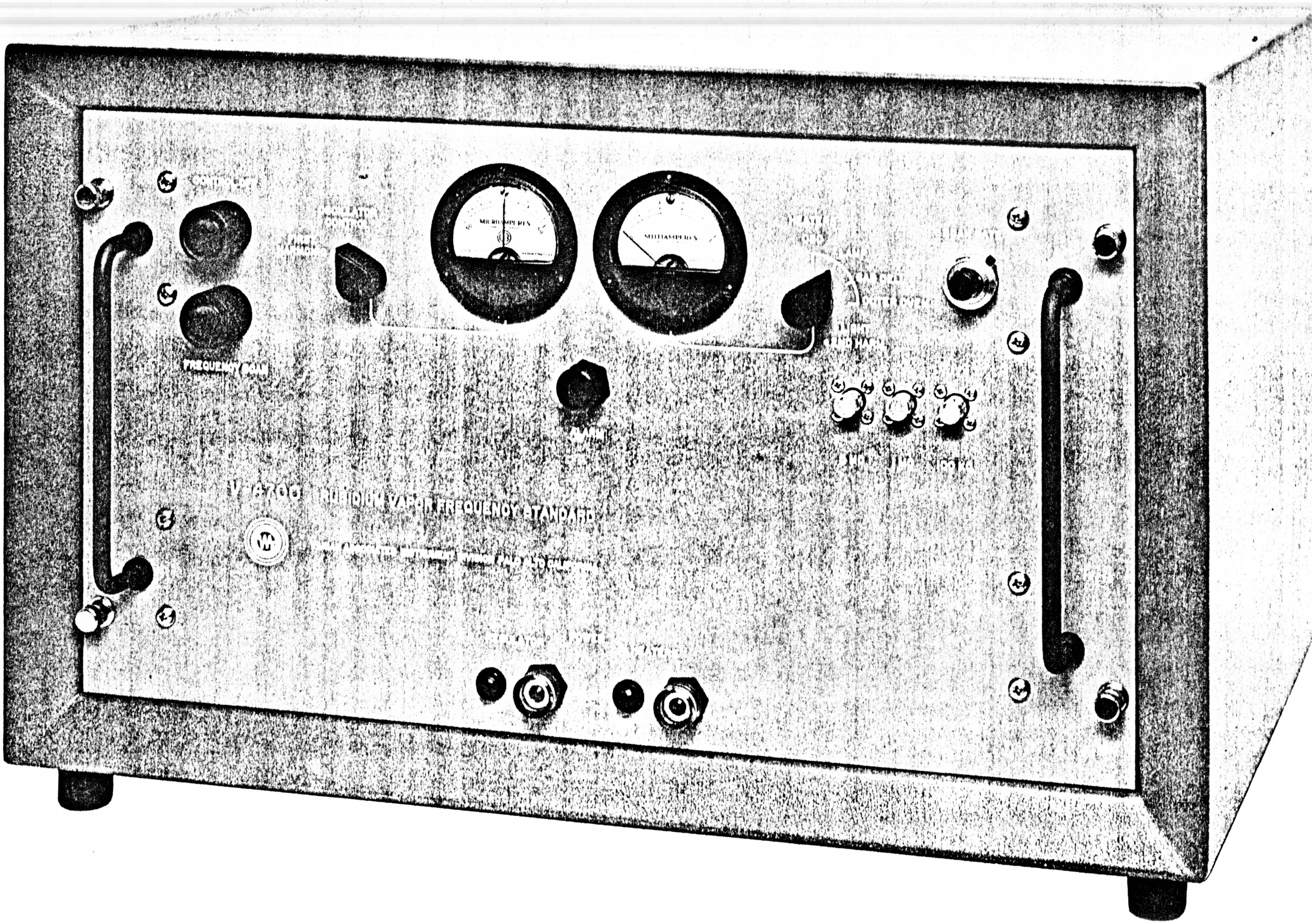


FIGURE 3-1. FRONT PANEL, V-4700A RUBIDIUM VAPOR FREQUENCY STANDARD

3.0 OPERATING INSTRUCTIONS

3.1 OPERATING CONTROLS AND METERING

3.1.1 V-4700A Rubidium Vapor Frequency Standard Front Panel (See Figure 3-1.)

3.1.1.1 Controls

Control	Function
CONTROL OFF	Breaks control loop by disconnecting the phase detector from the operational amplifier and shorting the integrating resistor associated with the operational amplifier.
FREQUENCY SCAN	Injects a current, controlled by the SCAN RATE control on the front panel, into the input of the operational amplifier. The operational amplifier integrates this current to give a voltage scan at its output. This scan is then applied to the control Varicap in the oscillator to provide a frequency scan.
SCAN RATE	This control injects zero current at a dial setting of about 500. Below 500 the OSCILLATOR CONTROL voltage will integrate upward with time. When used with the Rear Control MANUAL Frequency SET switch down, the SCAN RATE control becomes instead a direct fixed control on oscillator frequency.
REGULATOR	A circuit breaker on the input to the regulator.

HEATERS	A circuit breaker on the power to the heaters.

3.1.1.2 Meters

Meter Position	Function
HEATERS-OSC	Monitors the voltage across the heater winding in the crystal oscillator.
HEATERS-LAMP	Monitors the voltage across the heater winding in the lamp-filter cell package.
HEATERS-GAS CELL	Monitors the voltage across the heater winding in the cavity.
HEATERS-OUTER OVEN	Monitors the voltage across the heater winding in the outer oven. With 28 vdc bus voltage, the heaters are delivering full power at a meter reading about 0.85 full scale.
LIGHT	Monitors light intensity by means of a photocell located in the lamp package. In normal operation reads about half scale.
2ND HARMONIC	Monitors the second harmonic level at the output of the preamplifier, and is an indication of signal strength when the system is locked.
FIRST HARMONIC	Monitors the voltage at the output of the phase detector. This voltage is positive if the microwave frequency is above the hyperfine frequency and negative if it is below.

	When the instrument is locked this voltage is zero.
OSCILLATOR CONTROL	Monitors the voltage applied to the control Varicap in the 5 mc oscillator.
	At this point it should be mentioned that the phase detector, the operational amplifier, and the Varicap circuitry in the 5 mc oscillator all use a floating ground which is held +11.5 v above chassis ground. FIRST HARMONIC and OSCILLATOR CONTROL metering is relative to this floating ground.

3.1.1.3 Lights

Lights	Function
ALARM	This light turns on when the second harmonic drops below some preset level.
REGULATOR	This light turns on when the REGULATOR circuit breaker is closed and a voltage appears at the regulator output.
HEATERS	This light turns on when the heater circuit breaker is closed and heater voltage is available.

3.1.2 V-4760 Power Supply Front Panel (See Figure 3-2)

3.1.2.1 Controls

Control	Function
AC	The AC switch switches the 60 cycle power to the Sola constant voltage transformer-

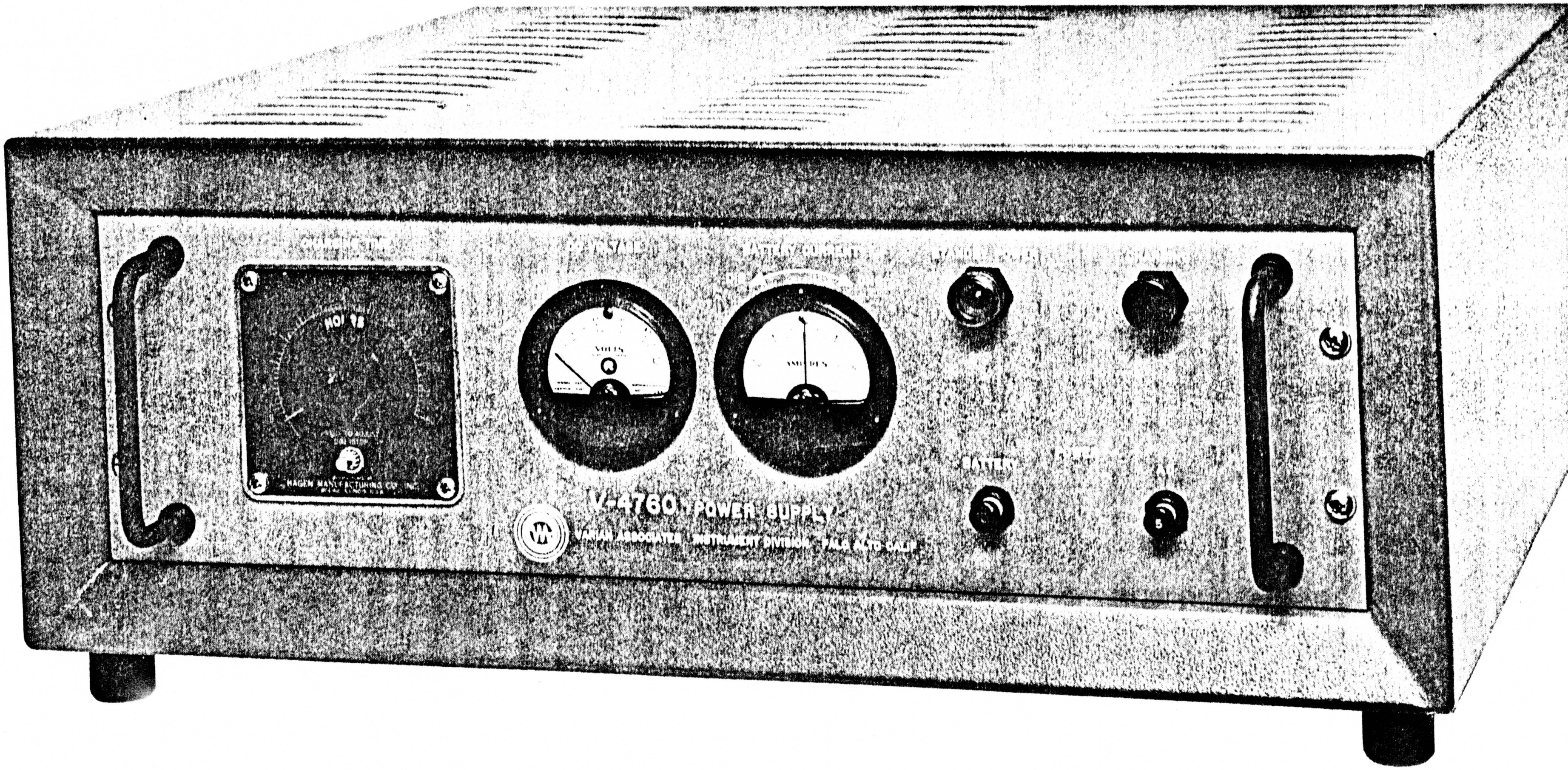


FIGURE 3-2. FRONT PANEL, V-4760 POWER SUPPLY

rectifier primary power source.

BATTERY — When closed, the BATTERY switch places the standby batteries in parallel with the primary d-c power.
The AC and BATTERY switches are all circuit breakers.

CHARGING TIME — When the CHARGING TIME timer is activated, the voltage on the d-c power bus is raised from its normal 28 v to 31 v. After the unit has been operated on nickel-cadmium standby batteries, it is recommended that the batteries be overcharged at 31 v for a time equal to the discharge time of the batteries. When the timer reaches zero, the d-c power bus voltage is dropped to its normal value.

3.1.2.2 Meter

Meter Position	Function
DC VOLTAGE	Meters the output voltage.
BATTERY CURRENT	Meters the current flow to and from the batteries.

3.1.2.3 Lights

Light	Function
STANDBY POWER	This light is on if standby batteries are used and the output disappears from the rectifier. It shows that current is being drawn from batteries.

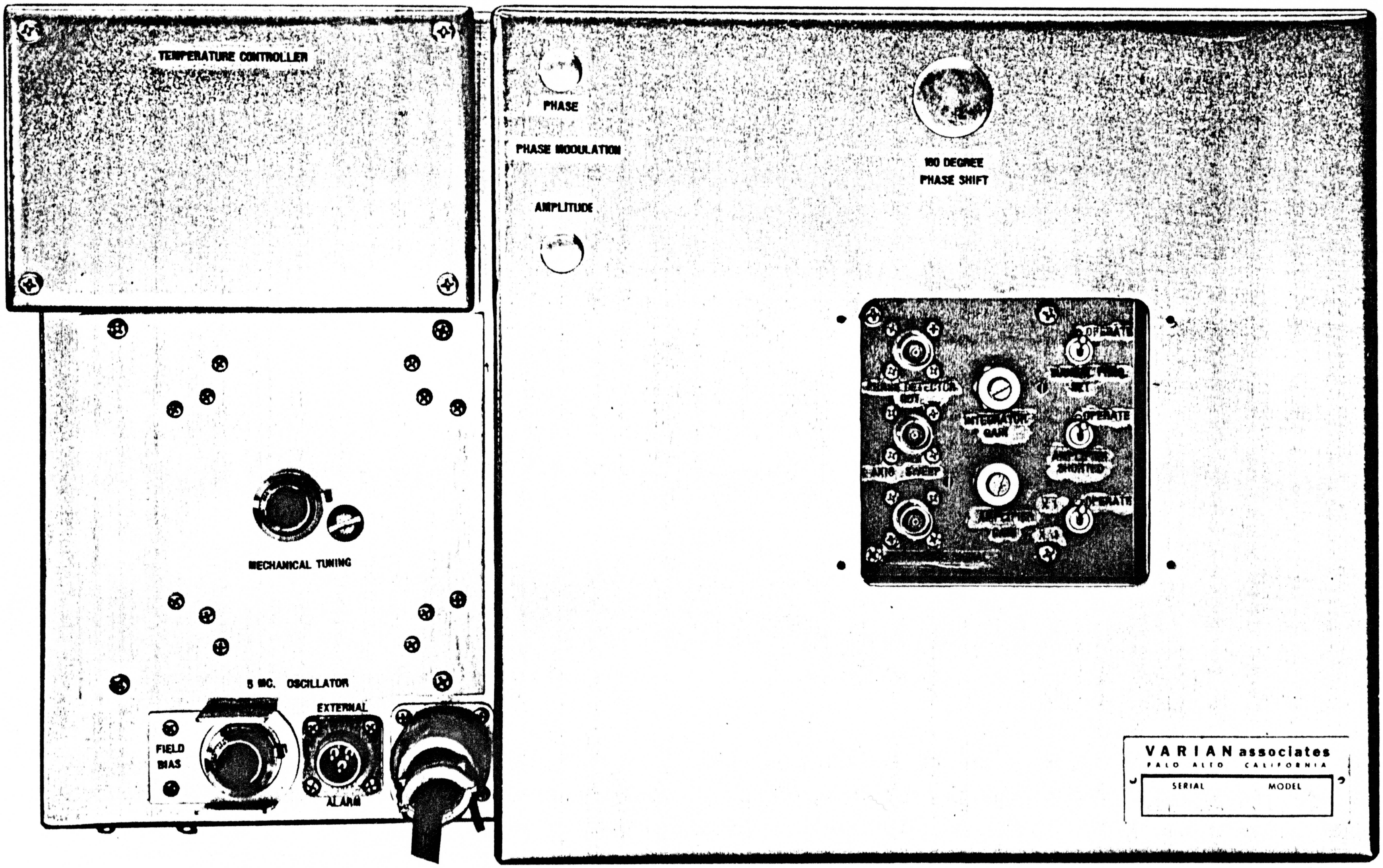


FIGURE 3-3. REAR VIEW, V-4700A FREQUENCY STANDARD

CHARGING	This light is on when the CHARGING TIME timer is used to raise the d-c bus voltage to 31 v.

3.1.3 V-4700A Rubidium Vapor Frequency Standard Controls, Adjustments, and Monitoring Points

3.1.3.1 Rear Controls (See Figure 3-3.)

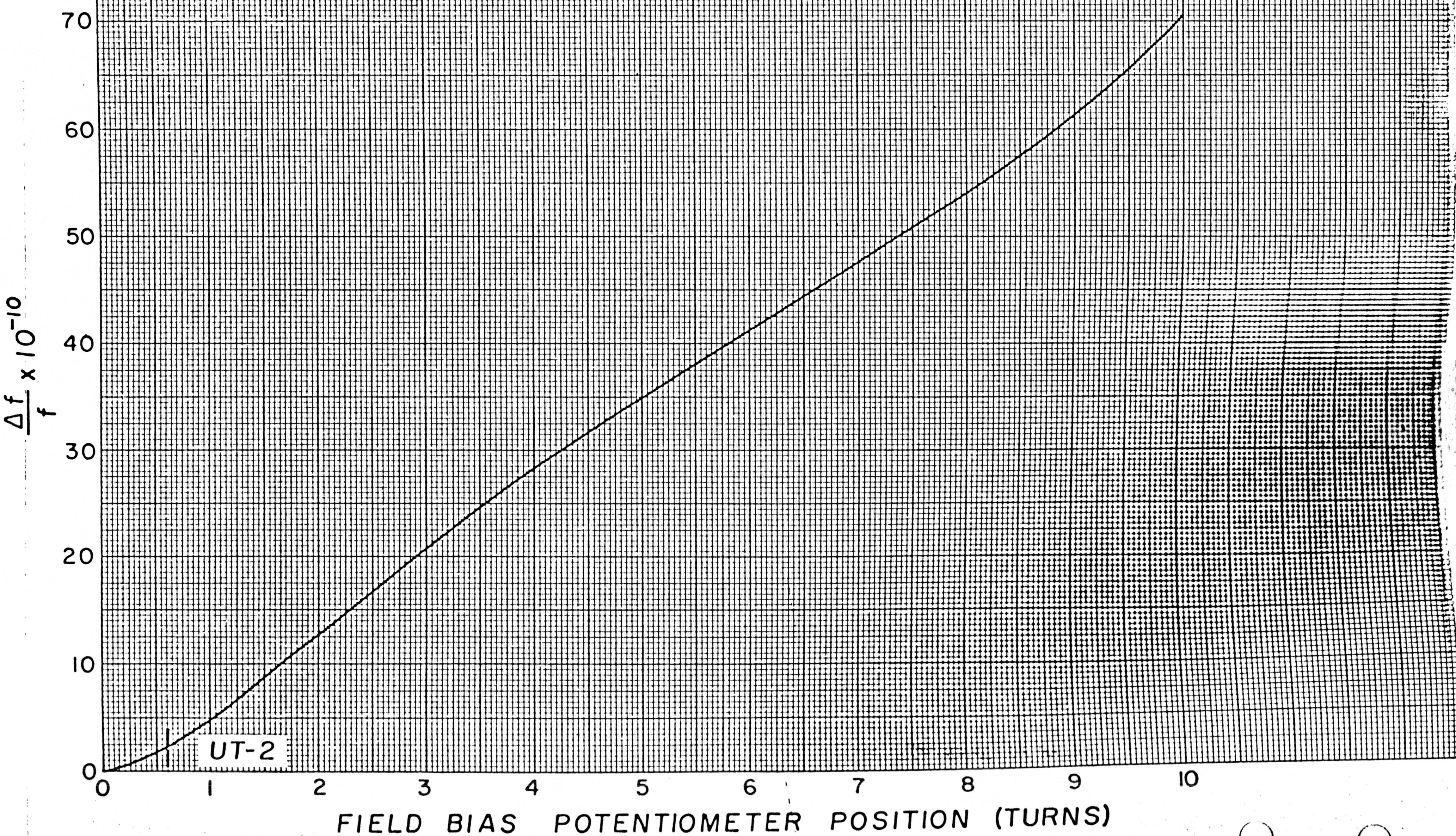
Control	Function	Normal Position
OPERATE-MANUAL FREQ SET	In the MANUAL FREQ SET position the amplifier output is disconnected from the oscillator control Varicap and a voltage controlled by the SCAN RATE front panel control is applied directly in this Varicap. This voltage can be monitored at the OSCILLATOR CONTROL metering position.	Operate
OPERATE-AMPLIFIER SHORTED	In the AMPLIFIER SHORTED position the input to the filter amplifier is shorted.	Operate
ZERO DRIFT	This control is accessible through a hole in the side of the servo cover adjacent to the 5 mc oscillator. The AMPLIFIER SHORTED switch and the ZERO DRIFT adjustment are used together to remove offsets in the phase detector and operational amplifier. Set this switch to the AMPLIFIER SHORTED position. With the OPERATE- MANUAL FREQ SET switch in the OPERATE position, use the FREQUENCY SCAN push button and SCAN RATE	

control to bring the OSCILLATOR control voltage near the middle of its range. Engage a small screwdriver in the ZERO DRIFT control and adjust it until the OSCILLATOR control voltage no longer drifts. If an appreciable drift exists initially, it may be necessary to recenter the meter with the FREQUENCY SCAN system several times before the adjustment is completed.

X1 OPERATE -X.1	In the X.1 position the gain of the filter amplifier is reduced by a factor of 10. This position is used in the alignment of the instrument.	X1 Operate
AMPLIFIER GAIN.	This gives continuous control over the gain of the filter amplifier.	Maximum (full right)
INTEGRATOR GAIN	This provides a range of gain control on the operational amplifier (integrator) by varying the series input resistance. AMPLIFIER GAIN and INTEGRATOR GAIN will be set at the factory. The normal positions listed above are approximations to the point where these controls will be set. These controls will be discussed later in Section 3.4.3.	Minimum (full left)
MODULATION AMPLITUDE, MODULATION PHASE INVERSION	MODULATION AMPLITUDE, MODULATION PHASE, AND PHASE INVERSION controls are accessible through holes in the back of servo cover.	

AVERAGE SLOPE = 6.4×10^{-10} PER TURN
AVERAGE SLOPE = 6.4×10^{-12} PER DIAL UNIT
ZERO FIELD FREQUENCY = -132×10^{-10} RELATIVE TO A-1

SERIAL No. 14



VARIAN ASSOCIATES
Palo Alto, California
September 26, 1962

POTENTIOMETER SETTING (TURNS)	$\frac{\Delta f}{f} \times 10^{-10}$
.10	0
.20	.317
.40	.940
.60	2.09
.80	3.23
1.00	4.69
1.50	8.72
2.00	12.8
2.50	16.9
3.00	20.8
3.50	24.6
4.00	28.2
4.50	31.8
5.00	35.0
5.50	38.1
6.00	41.3
6.50	44.4
7.00	47.4
7.50	50.7
8.00	54.0
8.50	57.2
9.00	61.2
9.50	65.4
10.00	70.6

These controls are factory set at the optimum points. These controls will be discussed further in Section 3.4.1.

MECHANICAL TUNING	This control provides a mechanical tuning of the 5 mc crystal oscillator over a range of approximately 2 x 10^{-6}. In operation of the instrument this control is used to occasionally rezero the OSCILLATOR CONTROL voltage as the crystal oscillator ages.	
FIELD BIAS	This dial controls the d-c magnetic field applied axially on the gas cell and provides a means of fine tuning on the system.	See Fig. 3-4 Frequency Calibration chart.

3.1.3.2 Rear Connections

Connection	Function
EXTERNAL ALARM	At the same point at which the ALARM light is turned on, a set of alarm contacts are activated. When the ALARM light is on, pins B and A are tied together and pin C is floating. When the ALARM light is off, pins C and B are tied together and pin A is floating.
PHASE DETECTOR	This provides an a-c coupled connection to the output of the phase detector.
X-AXIS SWEEP	This provides a triangular wave X-axis oscilloscope sweep, synchronized with the phase modulation of 800 mv peak-to-peak.

RESONANCE SIGNAL	At this point the output of the preamplifier may be observed.

3.1.4 V-4760 Power Supply Rear Connections

Connection	Function
BATTERY	The cable from the battery is attached to this plug. Pins A, B, and C are positive and pins D, E, and F are negative. On the battery end of the cable, be careful to observe proper polarity -- THE BLACK END IS CONNECTED TO NEGATIVE BATTERY VOLTAGE, THE WHITE END IS CONNECTED TO POSITIVE BATTERY VOLTAGE.

3.2 POWER REQUIREMENTS

3.2.1 V-4700A Rubidium Vapor Frequency Standard

The power requirements are 24-36 v dc at 2.0 amps in normal ambient temperatures and at 2.5 amps at the lowest operating ambient at 15° C.

3.2.2 V-4760 Standby Power Supply

The unit operates from 117 $\pm$ 10 v 60 cps line power. If standby batteries are used, these will be located externally to the units and be connected by the cable running from the bracket on the rear of the power supply to the battery terminals. It is recommended that nickel-cadmium batteries from the Nicad Division, Gould-National Batteries, Inc., Easthampton, Massachusetts, be used. For instructions refer to booklet 227 from this organization. Twenty cells must be used in series

to reach the proper voltage. After the unit has been powered by the standby batteries, it is recommended that the batteries be overcharged, using the CHARGING TIME timer for a length of time equal to the discharge time on the batteries. Always check water level before and after each charge.

3.3 TURNING THE INSTRUMENT ON

The following instructions pertain to the operation of the V-4760 Standby Power Supply.

NOTE

IF OTHER SOURCES OF POWER ARE USED CERTAIN OBVIOUS CHANGES WILL BE REQUIRED.

Turn AC power on; the dc voltage should read 28 v. If standby batteries are used, turn the BATTERY switch ON. Turn the HEATER and regulator switches ON. Since the thermally controlled elements will be cold, the HEATER-OSC, LAMP, GAS CELL and OUTER OVEN should read full on. To increase heater power during initial warm-up, the CHARGING TIME timer may be set at approximately 1 hour. If this feature is used, do not turn BATTERY switch ON until the timer has turned itself OFF.

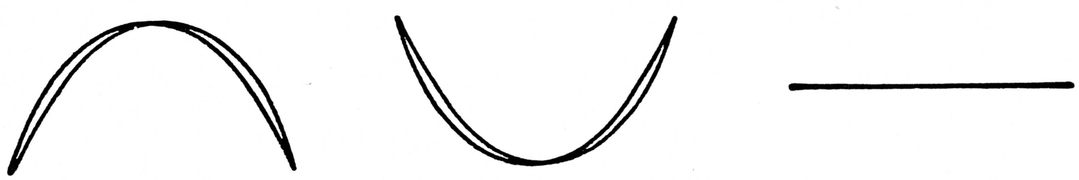
Switch the right hand meter to LIGHT. The lamp should turn on in about one minute and give a reading about half-scale.

After about one hour, the OSCILLATOR, LAMP, GAS CELL, and OUTER OVEN heater voltages should start decreasing, indicating the temperatures are approaching their proper value. At this point, a signal may be observed. Press the FREQUENCY SCAN button and use the SCAN RATE control to sweep the OSCILLATOR CONTROL voltage through its range. During this swing, the instrument should lock which will be indicated by a

reading on the 2nd HARMONIC meter. If second harmonic is of sufficient amplitude, at this time the ALARM light will also go OFF. It is to be expected that for a period of about an hour the signal will continue to grow as the lamp and gas cell reach internal equilibrium. In the same period of time, the crystal oscillator will reach internal equilibrium and the OSCILLATOR CONTROL voltage should be brought to zero with the MECHANICAL TUNING adjustment on the oscillator.

3.4 ADJUSTMENT OF CONTROLS

To adjust controls an oscilloscope should be used with connections made to the jacks on the rear of the instrument. Figure 3-5 shows oscilloscope trace of the PHASE DETECTOR output when MANUAL FREQuency SET is used. In Figure 3-5-A the microwave frequency is above



(A) (B) (C)

FIGURE 3-5

the hyperfine frequency; in Figure 3-5-B, the microwave frequency is below the hyperfine frequency; and in Figure 3-5-C, the two frequencies coincide which is the condition that exists when the system is locked. Figure 3-6 shows a RESONANCE SIGNAL when the system is locked.

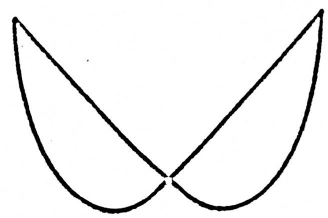


FIGURE 3-6

3.4.1 Modulation Controls

To adjust modulation controls observe the PHASE DETECTOR output on MANUAL FREQ SET, offset the microwave frequency from the hyperfine frequency by an amount which gives a phase detector output about one-half the maximum value obtainable. Adjust MODULATION AMPLITUDE control to nearly maximum the area under the oscilloscope trace. It is advisable to use an amplitude slightly less than that which gives maximum area. The front panel FIRST HARMONIC meter may be used as an aid in performing this operation. Adjust the MODULATION PHASE to bring the trace and retrace into coincidence; this gives maximum area upon the curve and maximizes the control voltage for a given frequency error. Figures 3-5-A and 3-5-C indicate correctly phased signals. Figure 3-7 indicates an incorrectly phased signal.

The PHASE DETECTOR output must be positive for the microwave frequency above the hyperfine frequency; this occurs for the SCAN RATE potentiometer below the value which these two frequencies coincide. If the sign of the PHASE DETECTOR output is incorrect, invert with the PHASE INVERSION switch.

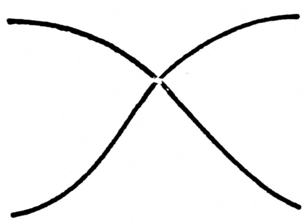


FIGURE 3-7

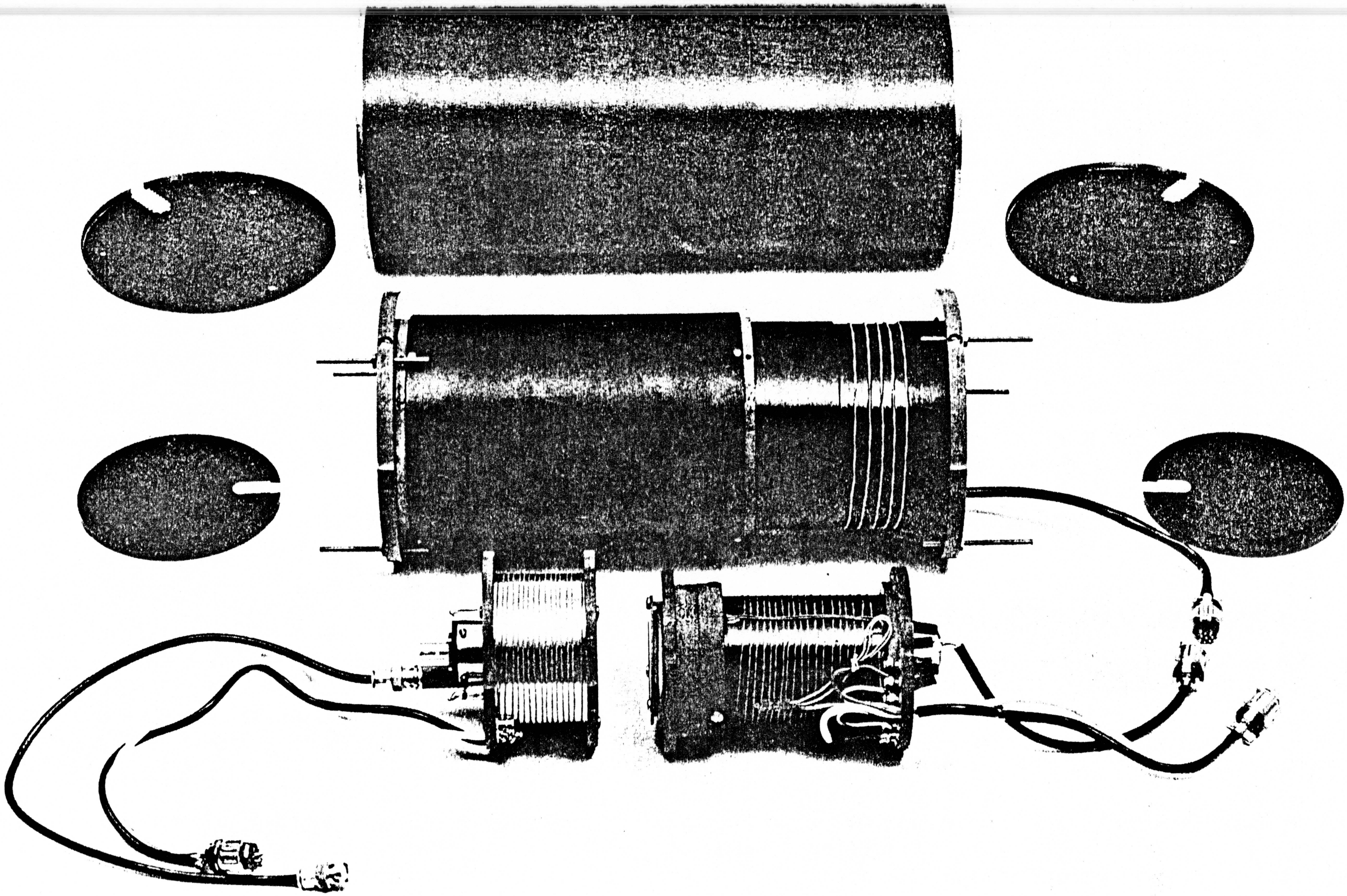


FIGURE 3-8. OPTICAL PACKAGE

3.4.2 Zero Drift

The procedure for using the ZERO DRIFT and AMPLIFIER SHORTED controls to remove phase detector and operational amplifier offsets has been discussed in Section 3.1.3.1. It is advisable, when it is not required that the instrument be in lock, to occasionally make this adjustment.

3.4.3 Amplifier and Integrator Gains

These two adjustments provide a means of controlling the loop gain of the frequency control system. Observe the PHASE DETECTOR output, use MANUAL FREQ SET and adjust the frequency to coincide with the hyperfine frequency. Adjust AMPLIFIER GAIN so the noise level at the PHASE DETECTOR output is 1.5 to 2.0 volts peak-to-peak. This then gives as high a gain as can be reasonably used without running into saturation, which occurs at 4 volts peak-to-peak.

Set INTEGRATOR GAIN at minimum value (full left) and lock the system. Increase INTEGRATOR GAIN until overshooting and control loop oscillations are noticed. Then reduce INTEGRATOR GAIN until overshooting disappears. This will set the loop gain roughly a factor of two below the value at which the loop will start oscillating. In some instances, because of a limited range of INTEGRATOR GAIN control, it may be necessary to reduce AMPLIFIER GAIN below the level set in the previous paragraph in order to stop loop oscillations.

3.4.4 Removal of the V-4700A from the Cabinet

Remove the two screws at the bottom rear of the instrument which clamps it to the bottom rails of the cabinet. Loosen the front panel screws and slide the unit forward out of the cabinet.

3.4.5. Adjustments in Optical Package

Figure 3-8 shows an exploded view with the cavity and lamp-filter cell package taken out of the outer oven. To remove the internal

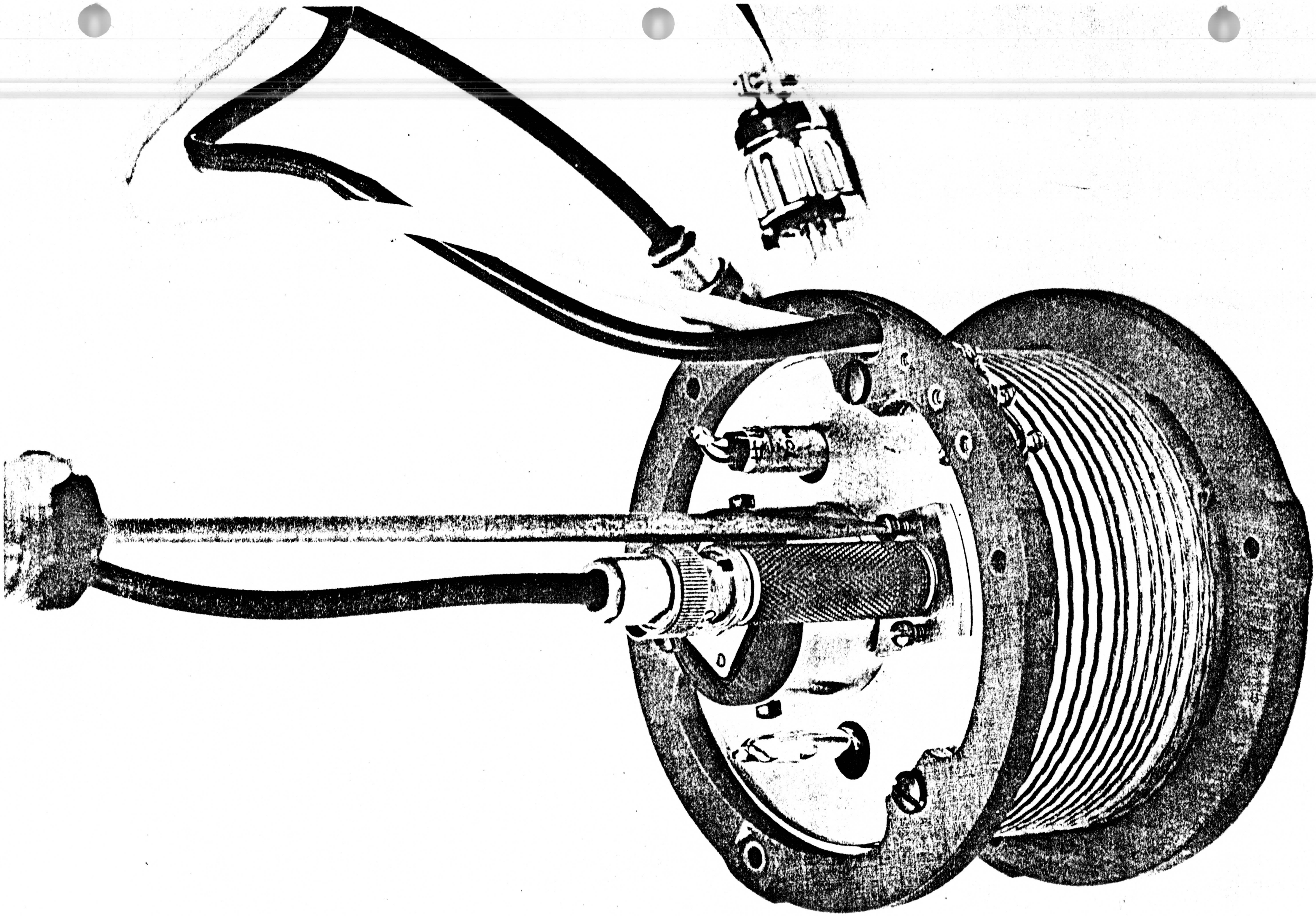


FIGURE 3-9. MICROWAVE POWER ADJUSTMENT

components, the end caps of the magnetic shield and outer oven must be removed. The cavity and lamp-filter cell package are held in place in the outer oven with tie rods. When replacing these assemblies, the tie rod nuts must be tightened securely to prevent any motion during shock, vibration, or acceleration of the instrument.

3.4.5.1 Adjustment of Microwave Power

The adjustment is made by adjusting the angle of the coupling loop in the cavity. Loosen the screws on the coupling loop locking plate as shown in Figure 3-9. Observe the PHASE DETECTOR output on an oscilloscope with MANUAL FREQ SET and the frequency slightly off resonance. Set gain at X.1 so amplifier saturation does not occur. As the coupling loop is rotated, changes in signal level and signal phase will be noted. Rotate coupling loop so a rather sharp minimum occurs in signal height. As the loop is rotated from this position and microwave power increases, the signal amplitude will increase with little phase shift. As the loop is further rotated, it will be observed that the signal height reaches a maximum value and considerable phase shift has now occurred. Set the microwave power by locking the loop with the two screws in the locking plate, at a level slightly below the value which gives the maximum signal. If required, adjust modulation phase as in section 3.4.1.

3.5 TEMPERATURE CONTROL ADJUSTMENTS

The temperature controllers are located on the rear of the main chassis. These controllers should normally require no adjustment. If for some reason they do, screwdriver adjustments are provided for temperature set points and loop gain in each controller. The left hand pot is the temperature control and the right hand pot is the gain control. Turn CW to increase both temperature and loop gain. The controllers are identified from top to bottom as follows: oscillator, lamp package, gas cell, and outer oven. The bottom board in the temperature control

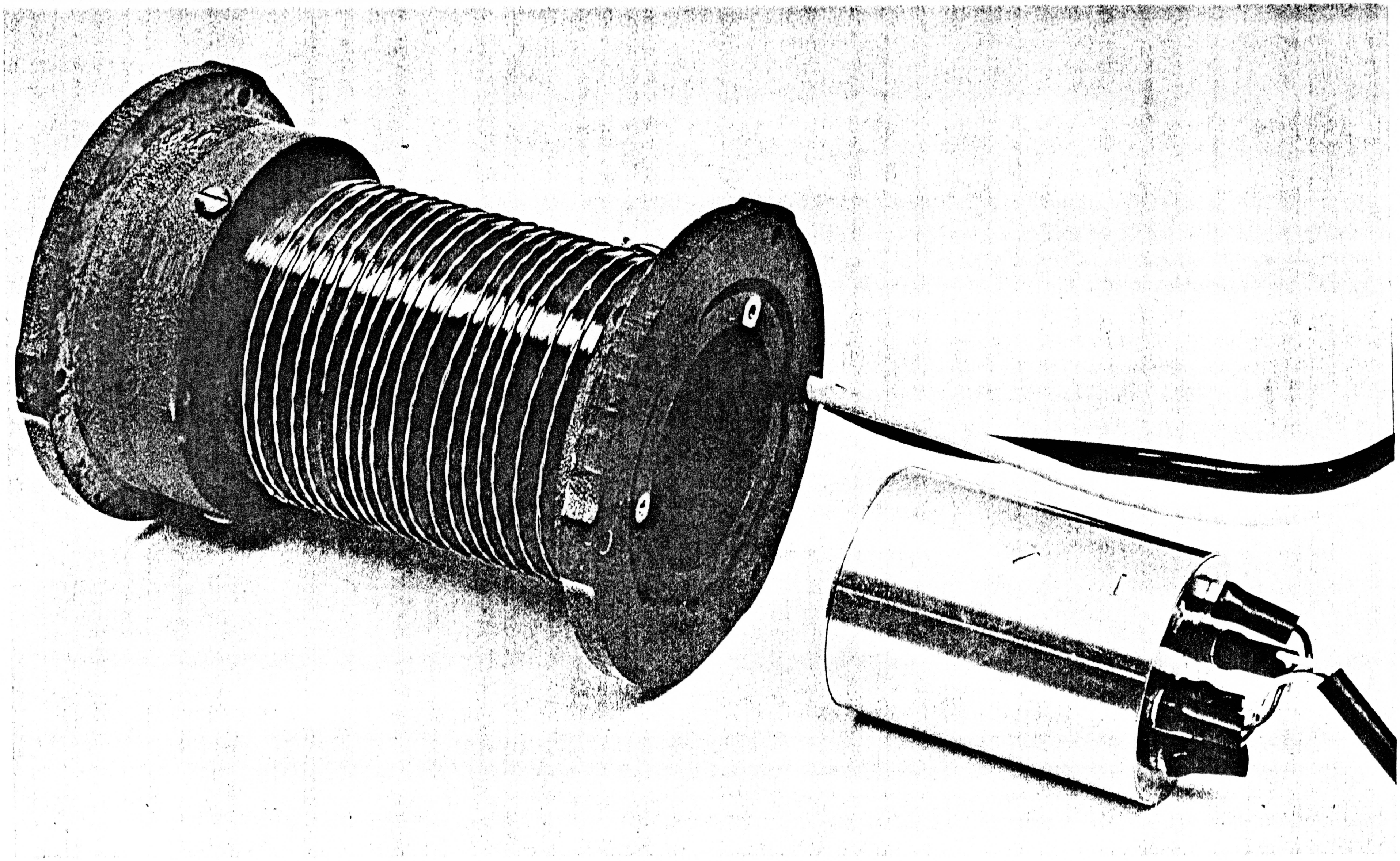


FIGURE 3-10. REMOVAL OF LAMP ASSEMBLY

package mounts the bridge excitation oscillator and phase detector driver circuits which are common to all four channels.

To make those temperature controller adjustments, the V-4700A must be removed from the case and the cover must be removed from the temperature controllers. WHENEVER THIS COVER IS REMOVED OR PUT ON, BE SURE ALL POWER IS TURNED OFF.

3.6 INTERNAL SERVO SYSTEM CIRCUITRY

Figure 3-11 shows the servo system with the cover removed. WHENEVER THIS COVER IS REMOVED OR PUT ON, BE SURE THE REGULATED POWER IS TURNED OFF.

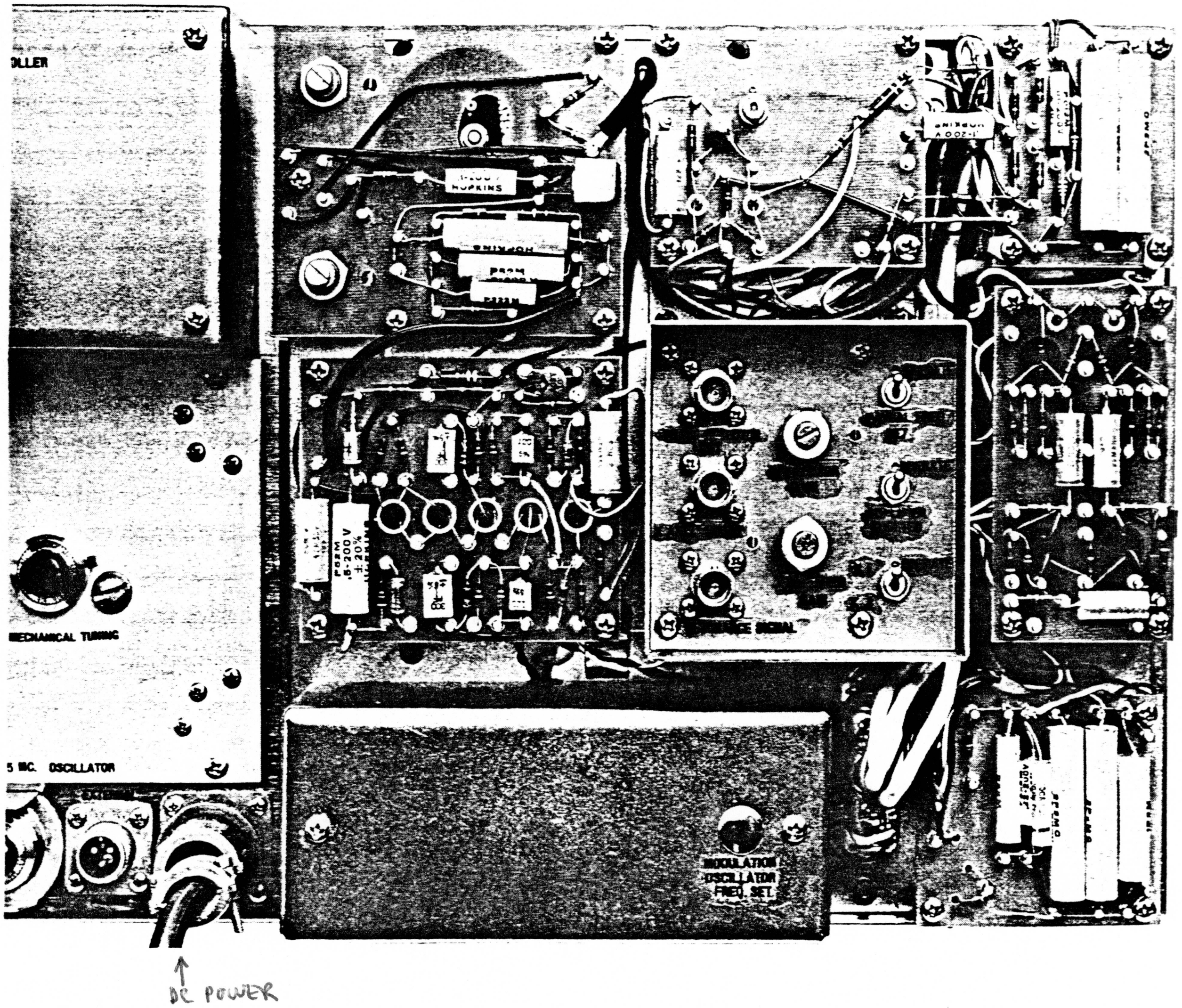
The various circuit boards of the servo system are labeled in this figure.

3.6.1 Adjustment of Modulation Oscillator and Second Harmonic Filter

The MODULATION OSCILLATOR and second harmonic bridged-tee filter have been factory adjusted to give very high second harmonic rejection. A need for adjustment will exist if a second harmonic signal is seen on the PHASE DETECTOR output when the system is locked. To do this the MODULATION OSCILLATOR FREQuency control, adjustable by a screwdriver through a hole in the internal MODULATION OSCILLATOR cover, and the bridged-tee variable resisor, which is the small trimpot on the second harmonic filter board, must be adjusted. To adjust the trimpot a long shank, narrow blade screwdriver is required. Adjust both controls until the second harmonic on the PHASE DETECTOR output is brought to zero.

3.6.2 Adjustment of 2nd Harmonic Meter and Alarm Light Sensitivity

These adjustments are made by screwdriver adjustments through small holes in the side of the main interior chassis, located in the rear of the cavity end of the optical package. The meter sensitivity and the alarm trip point are both increased by clockwise adjustment.



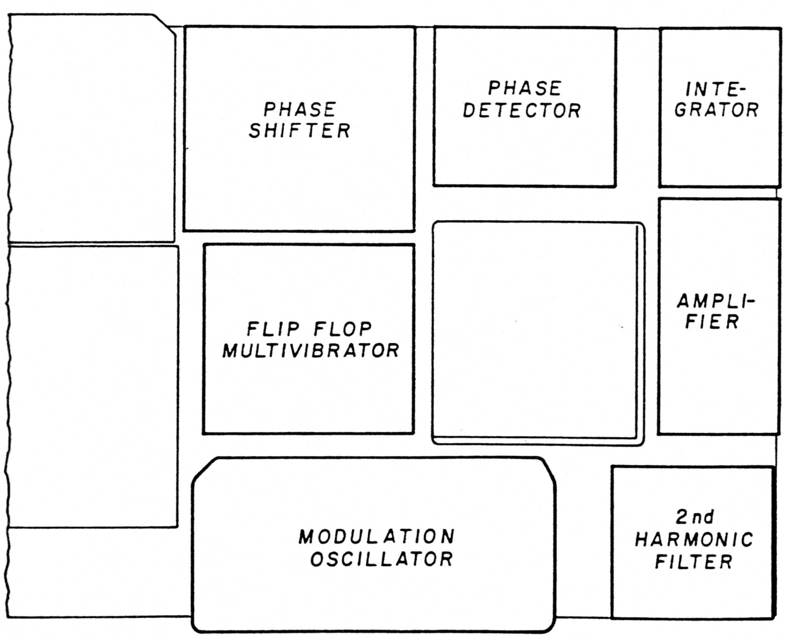


FIGURE 3-11. REAR VIEW,
SERVO SYSTEM LAYOUT

SCHEMATIC DIAGRAMS

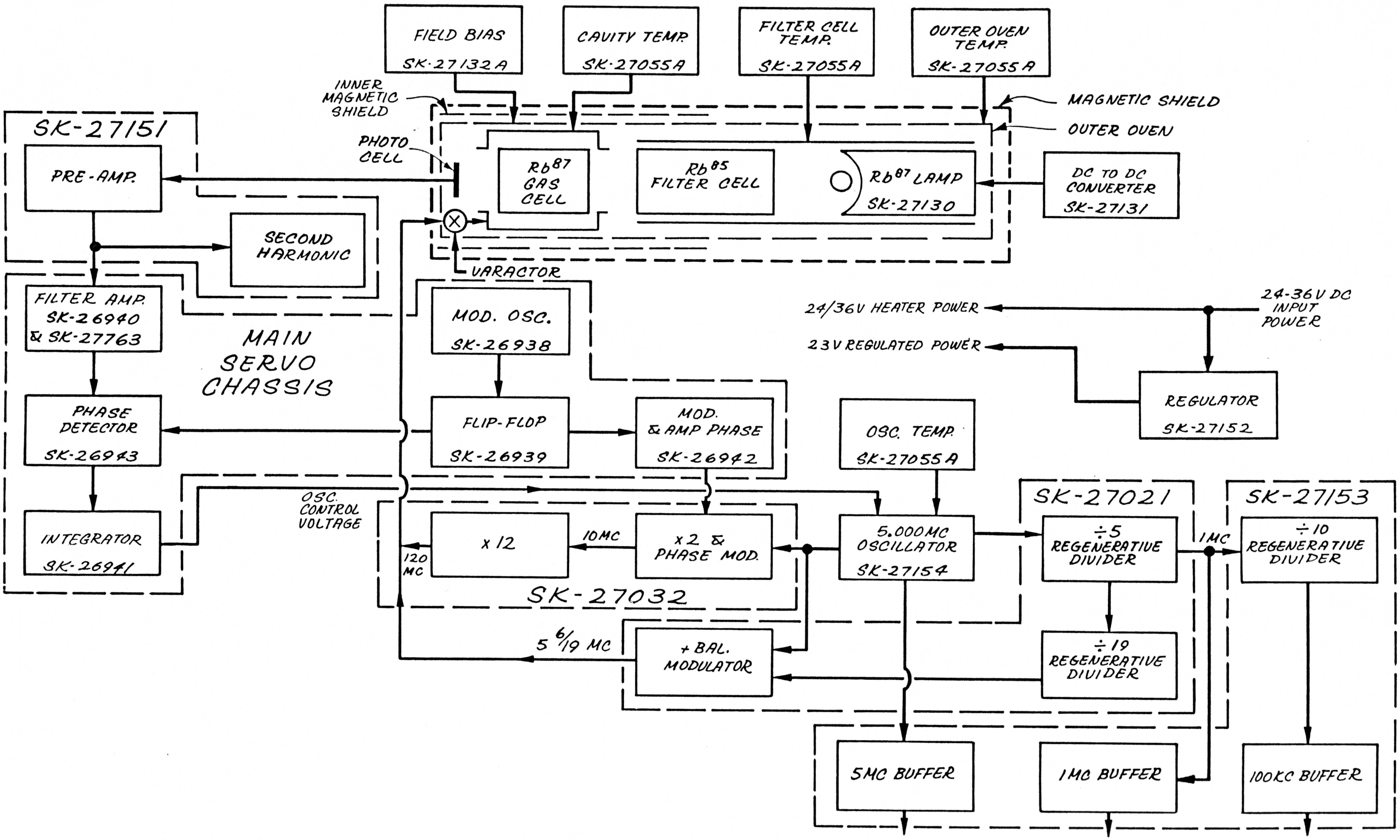
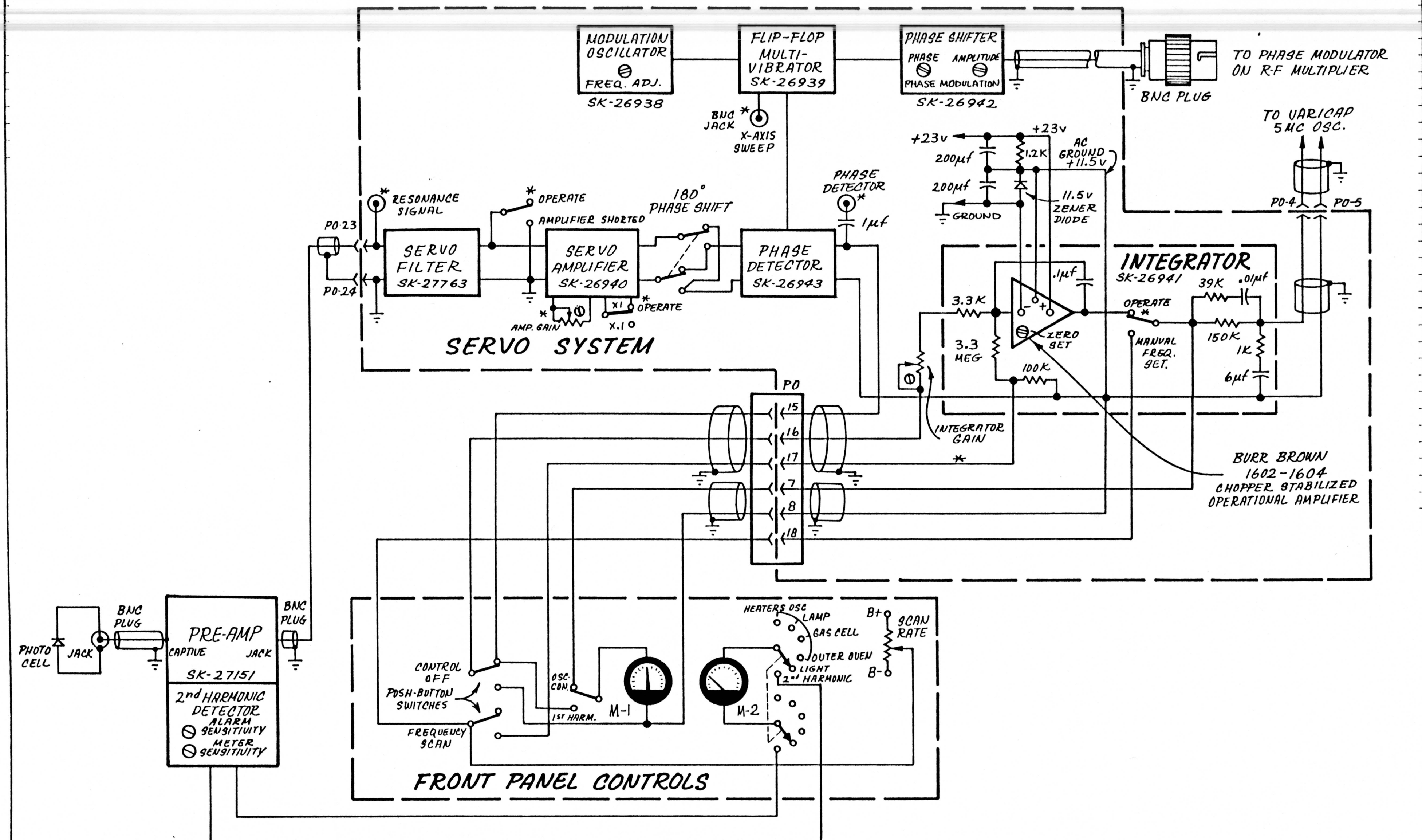


FIGURE 2-4 FREQUENCY STANDARD BLOCK DIAGRAM

DASH NO	TYPE OR MODEL		MBLY

REQ	PART NUMBER	MATE	ITEM



*
NOTE: THESE TEST POINTS AND SWITCHES AND CONTROLS ARE LOCATED ON THE TEST CONTROL PANEL IN THE SERVO SYSTEM.

DO NOT SCALE DRAWING

DRAWN	DATE	UNLESS OTHERWISE SPECIFIED			
W.W. HANDLEY	2/8/62	FRAC ±	DEC ±	ANG ±	FIN ✓
CHECKED	DATE	APPROVED		DATE	SCALE

SERVO SYSTEM BLOCK DIAGRAM

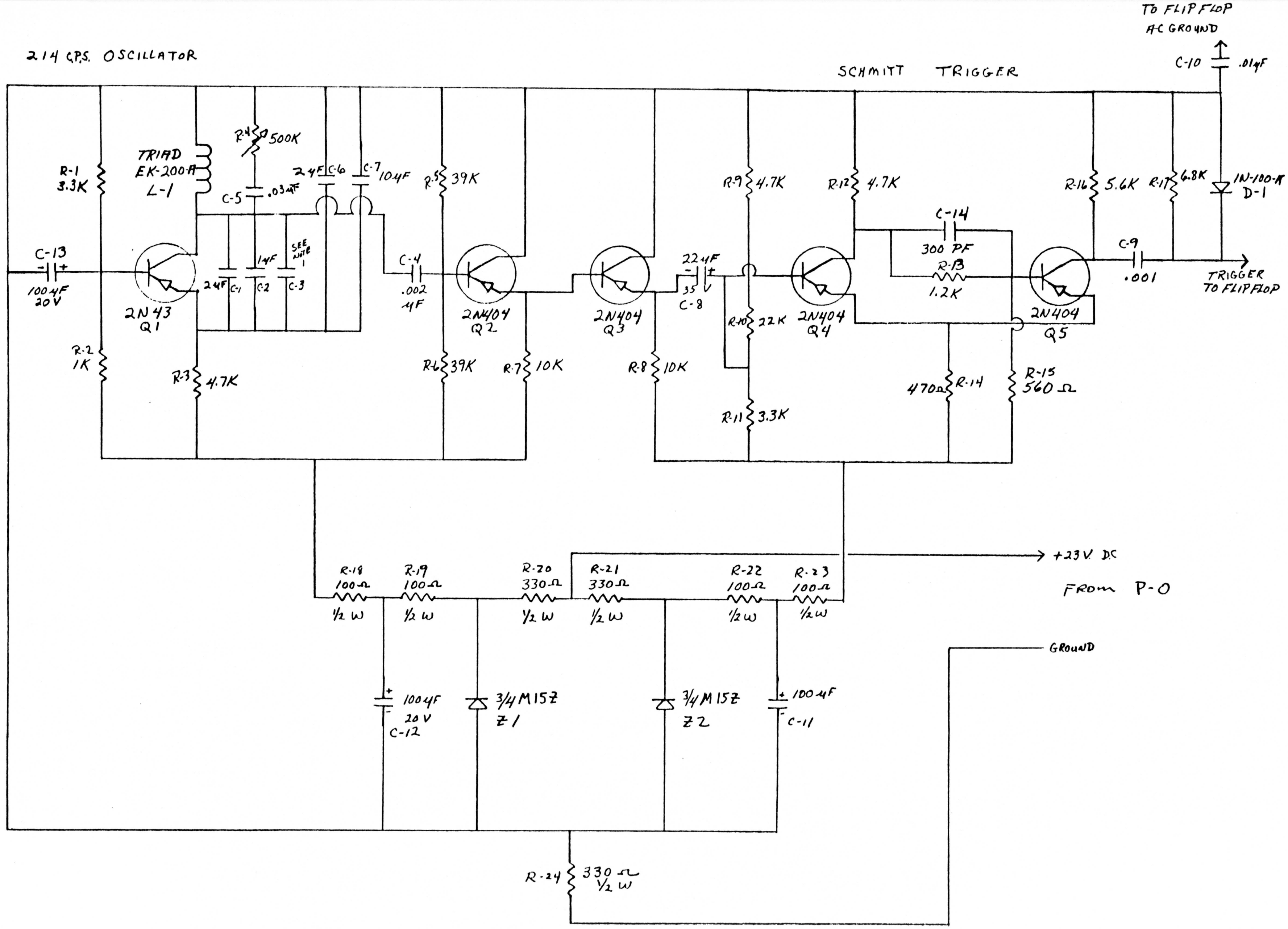
FINISH OR MFG SPEC | DIVISION | CLASS | CODE

VARIAN associates PALO ALTO · CALIFORNIA

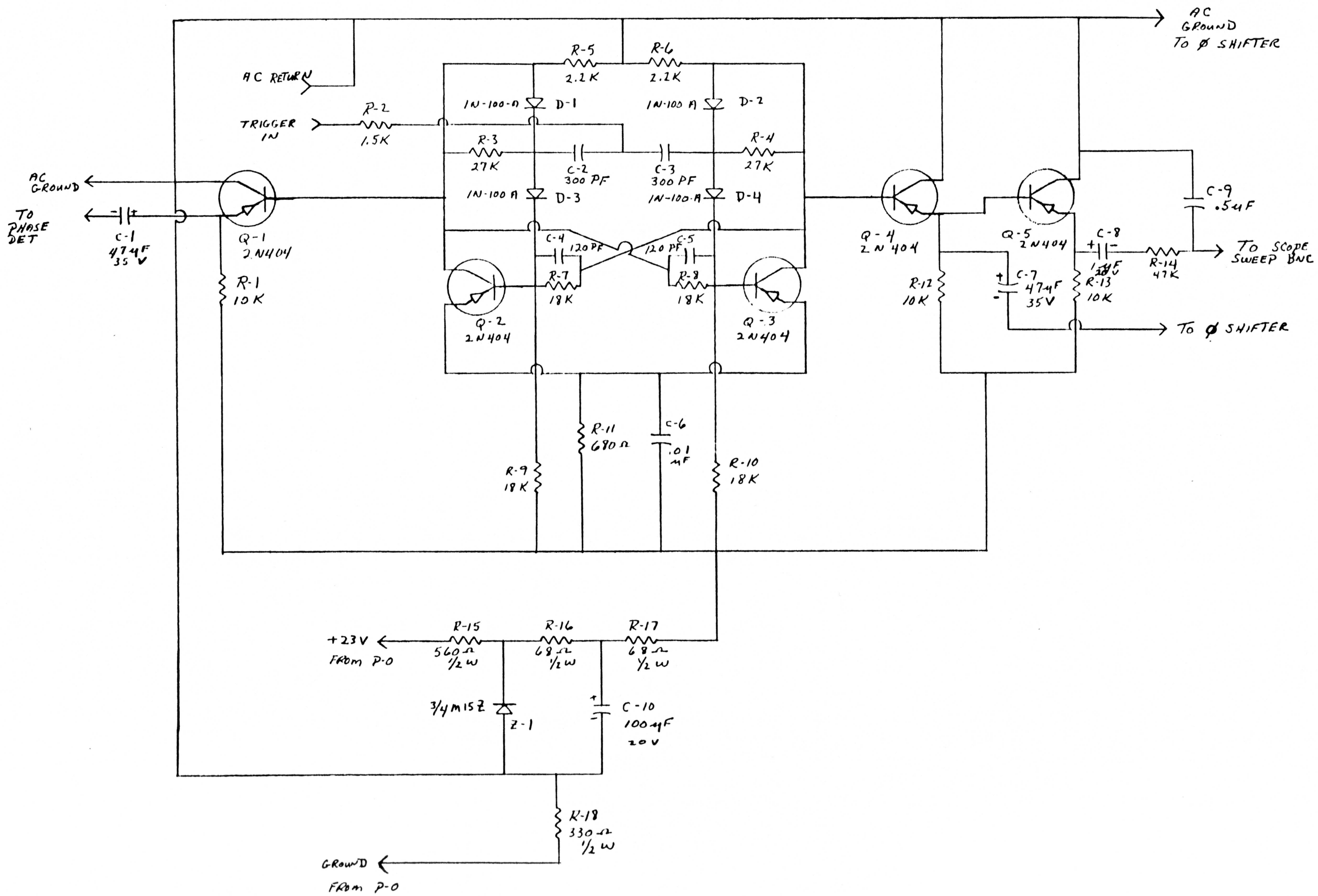
SIZE	DRAWING NO	REV
C	SK27723	

CHANGED FROM | NUM | ECO | DFT | CHK | DATE | REV

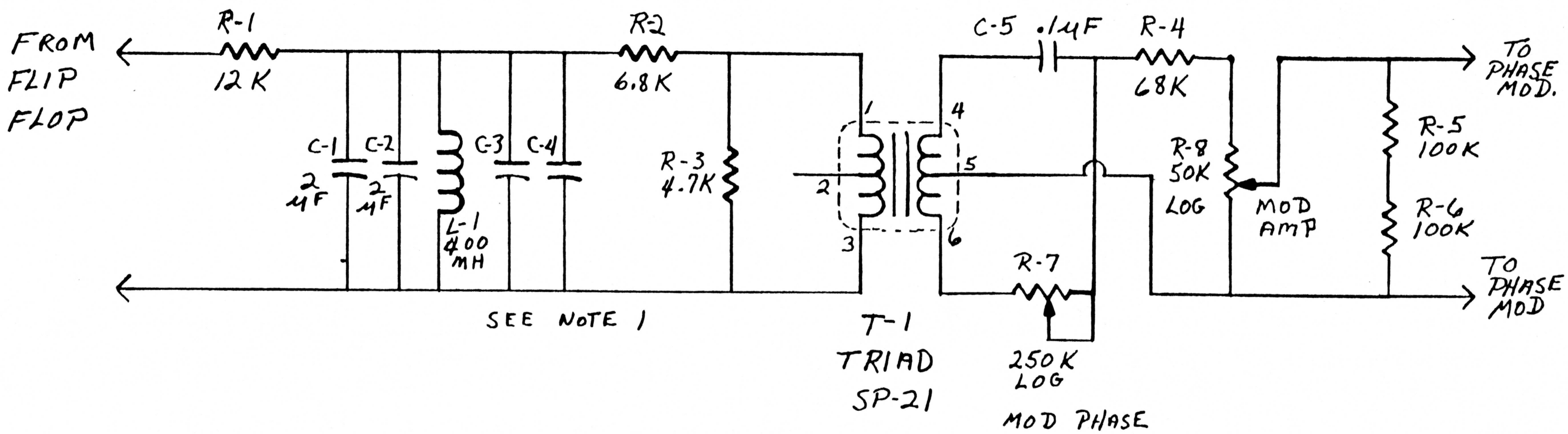
4165 APR59 LITHO IN U.S.A.



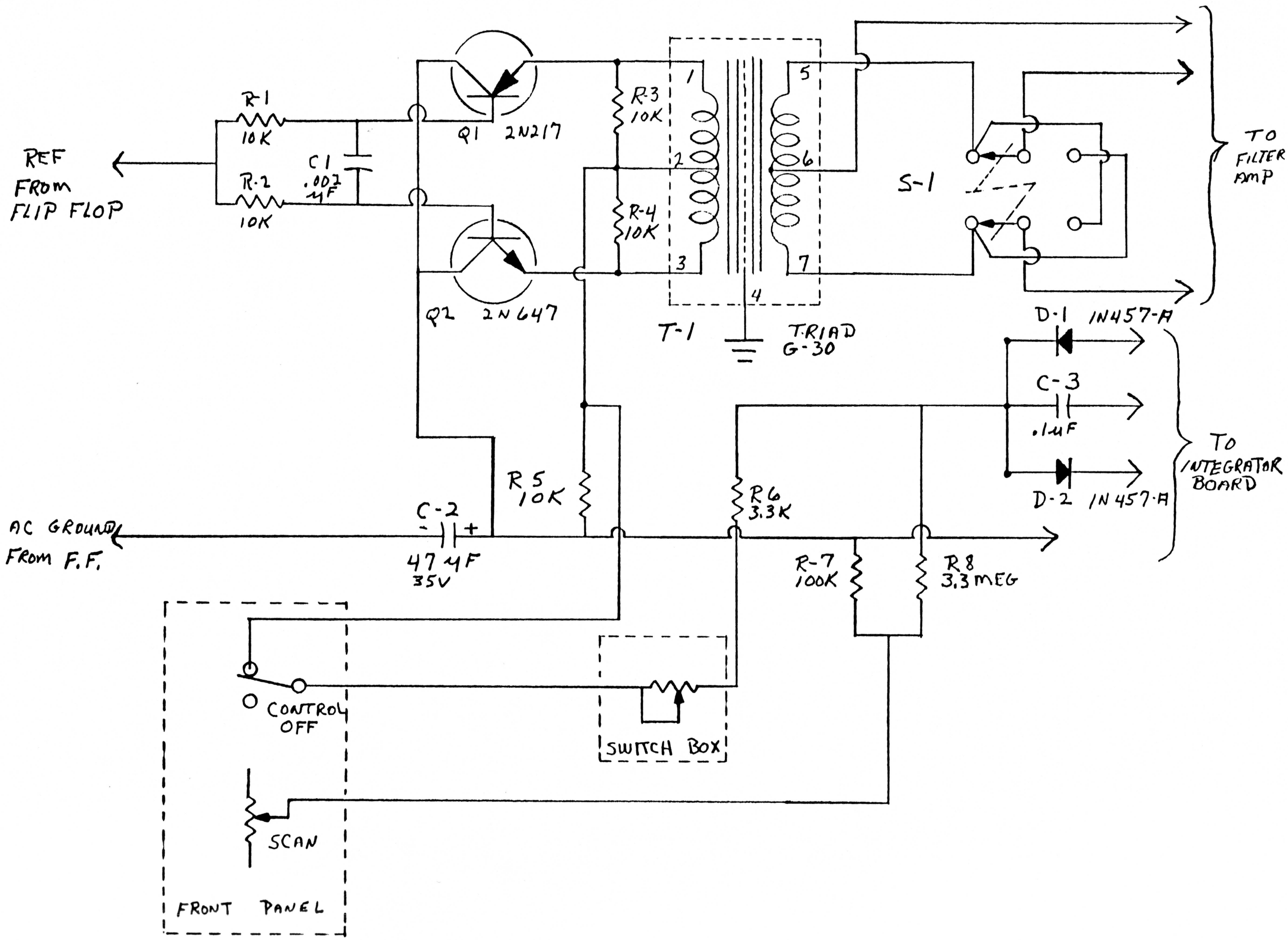
214 C.P.S. OSCILLATOR AND
SCHMITT TRIGGER SCHEMATIC



FLIP FLOP MULTIVIBRATOR SCHEMATIC
SK-26939



PHASE SHIFTER SCHEMATIC
SK-26942

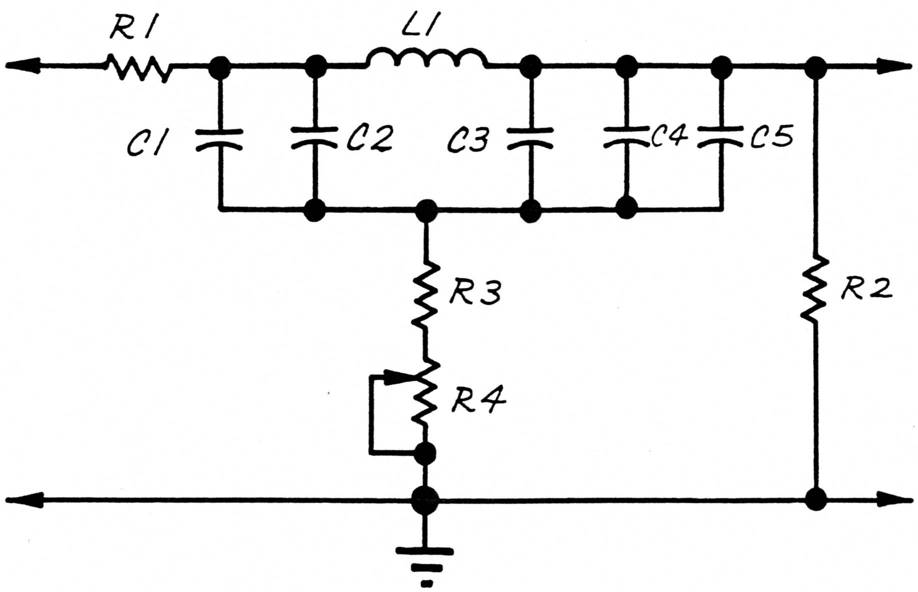


PHASE DETECTOR SCHEMATIC
SK-26943

DASH NO.	TYPE OR MODEL	NEXT ASSEMBLY	REQ	PART NUMBER	MATERIAL	ITEM
	V-4700A					

A SK-27763

DO NOT SCALE DRAWING



DRAWN	DATE	UNLESS OTHERWISE SPECIFIED:			
W.W. HANDLEY	3/20/62	FRAC ±	DEC ±	ANG ±	FIN. ✓
CHECKED	DATE	APPROVED	DATE	SCALE	

SERVO FILTER

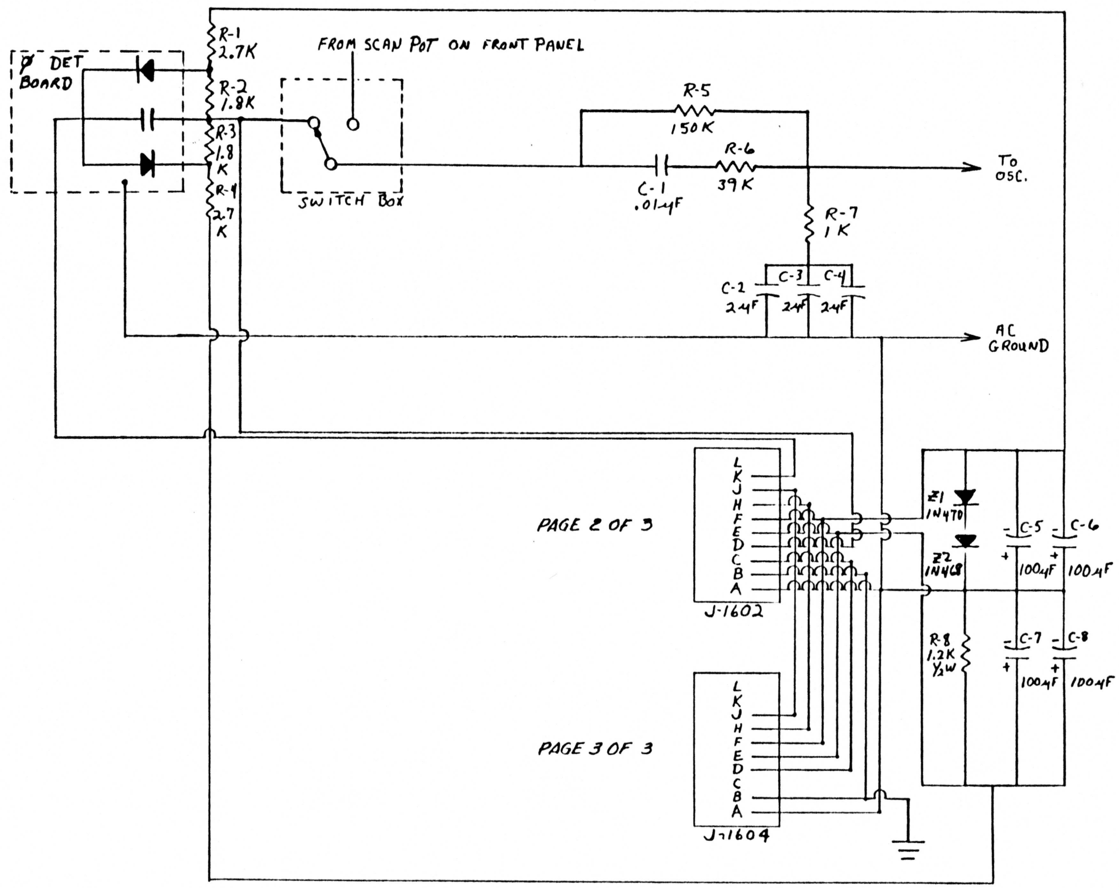
FINISH OR MFG SPEC	DIVISION	CLASS	CODE

VARIAN associates
PALO ALTO 2, CALIFORNIA

A	SK-27763	
SIZE	DRAWING NO.	REV

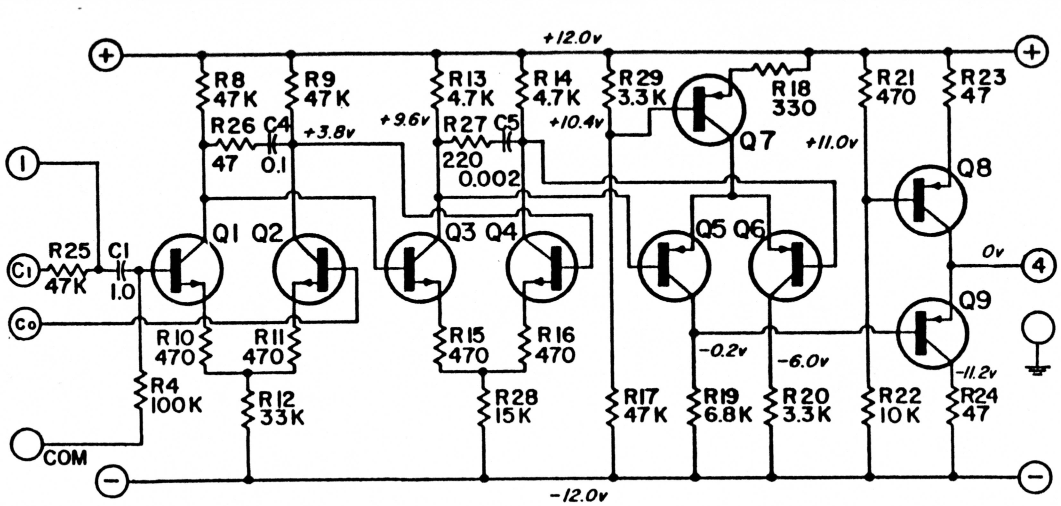
CHANGED FROM

NUM	
ECO	
DFT	
CHK	
DATE	
REV	



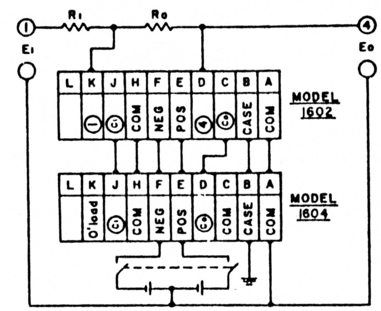
INTEGRATOR SCHEMATIC

SK-26941

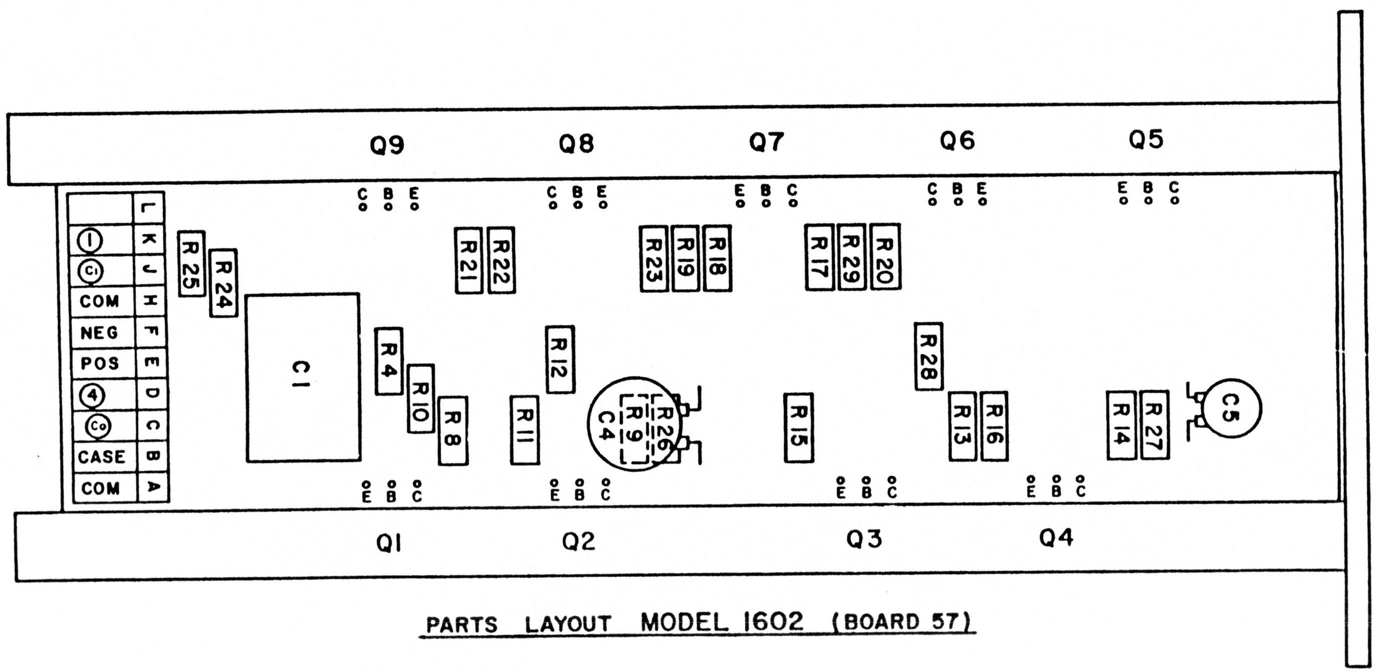


Q1, Q2, Q3, Q4 = 2N1121
Q5, Q6, Q7, = 2N188A
Q8, Q9 = 2N1172

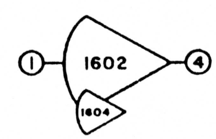
OPERATIONAL AMPLIFIER
MODEL 1602



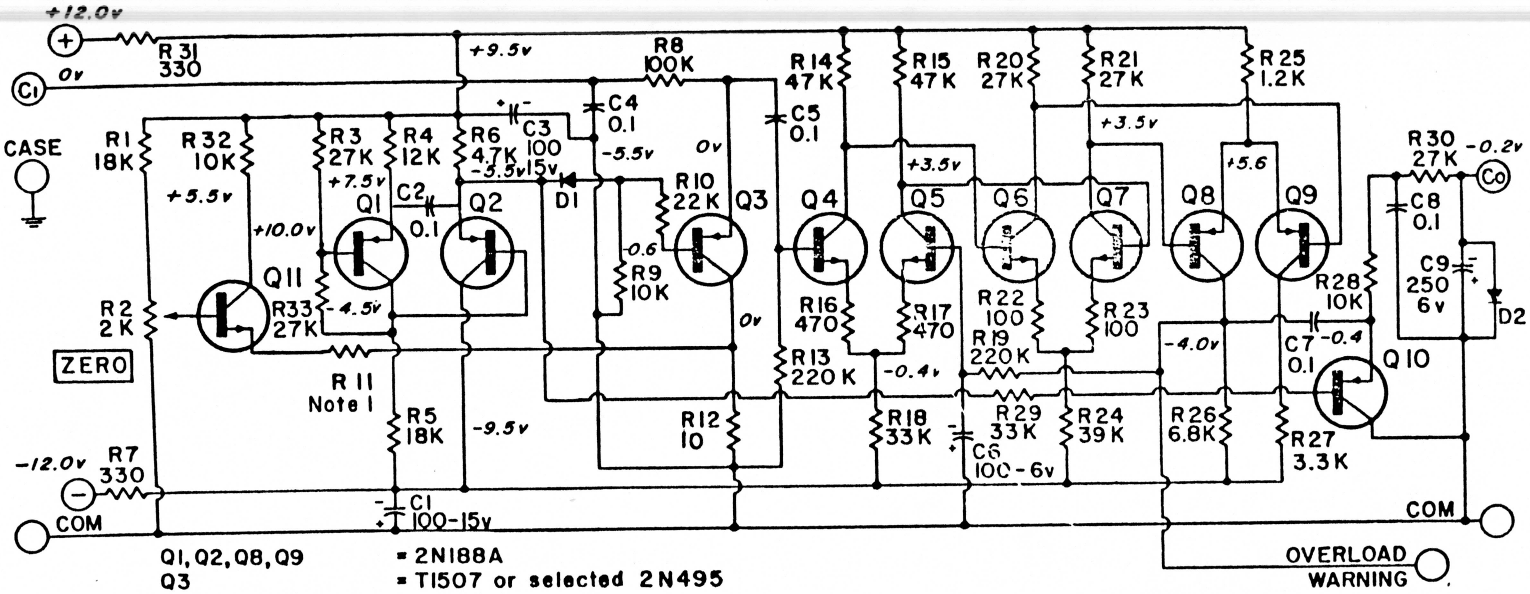
TYPICAL INSTALLATION
Socket Connections
(Buggie 4535)



PARTS LAYOUT MODEL 1602 (BOARD 57)



NOTATION
(Combined Units)

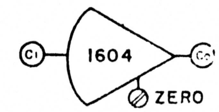


Q1, Q2, Q8, Q9 = 2N188A
Q3 = T1507 or selected 2N495
Q4, Q5, Q6, Q7, Q10, Q11 = 2N1121
D1, D2 = HB2

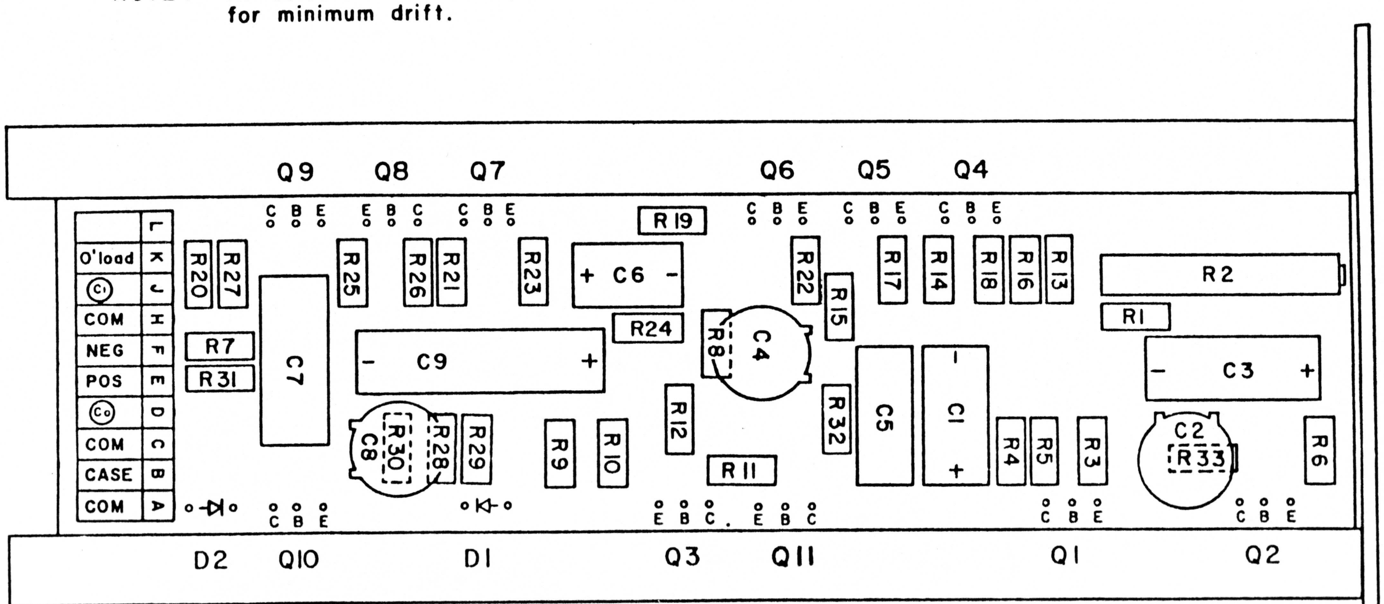
NOTE 1 - R11 selected to match Q11 & Q3 for minimum drift.

CHOPPER STABILIZING AMPLIFIER

MODEL 1604

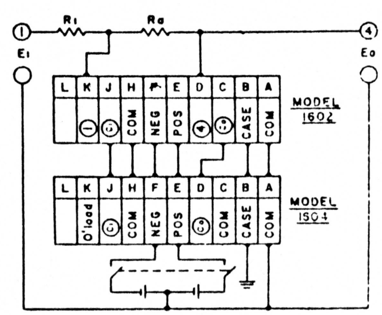


NOTATION
(Chopper Only)

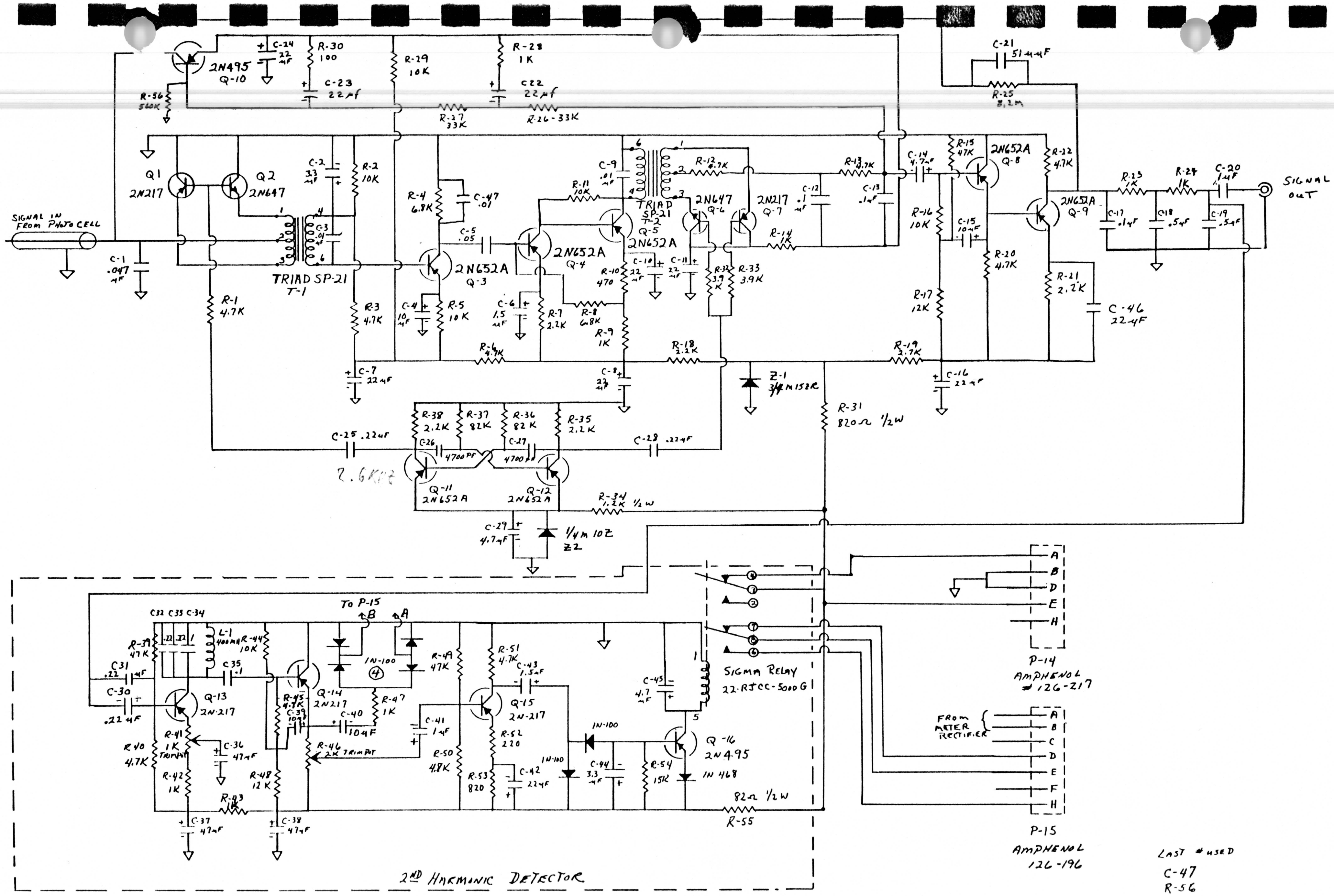


MODEL 1604

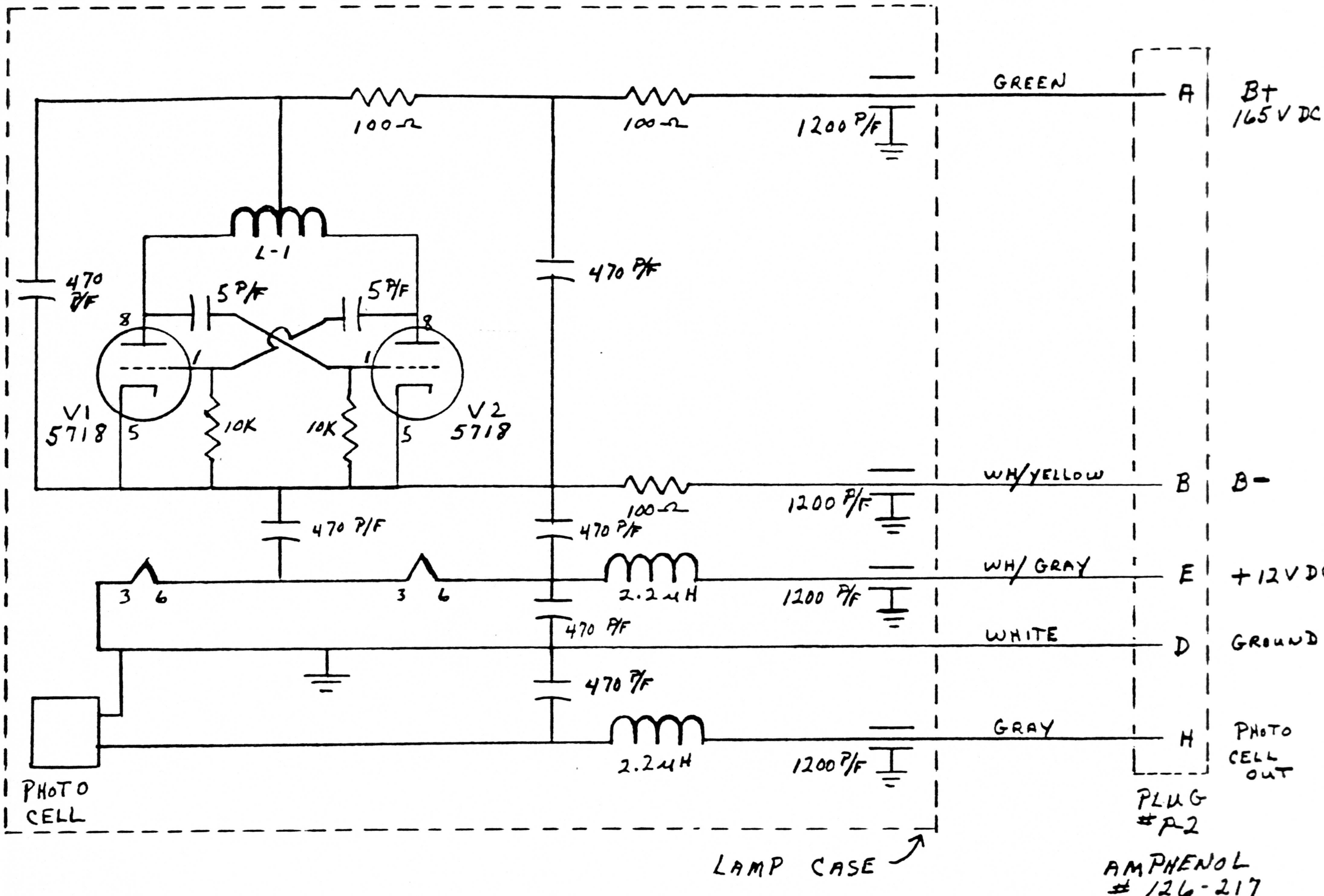
LAYOUT ON BOARD 29A



TYPICAL INSTALLATION
Socket Connections
(Buggie 4535)



TRANSISTOR PREAMP and 2ND HARMONIC DETECTOR SCHEMATIC SK-27151A

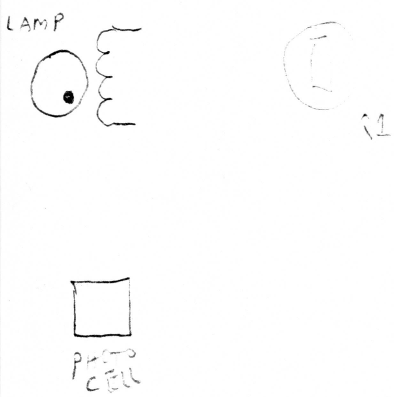


ALL GROUNDS CONNECT TO LAMP CASE

V4700

V-1, V-2 TYPE 5718

Rb LAMP EXCITER SCHEMATIC
SK-27130



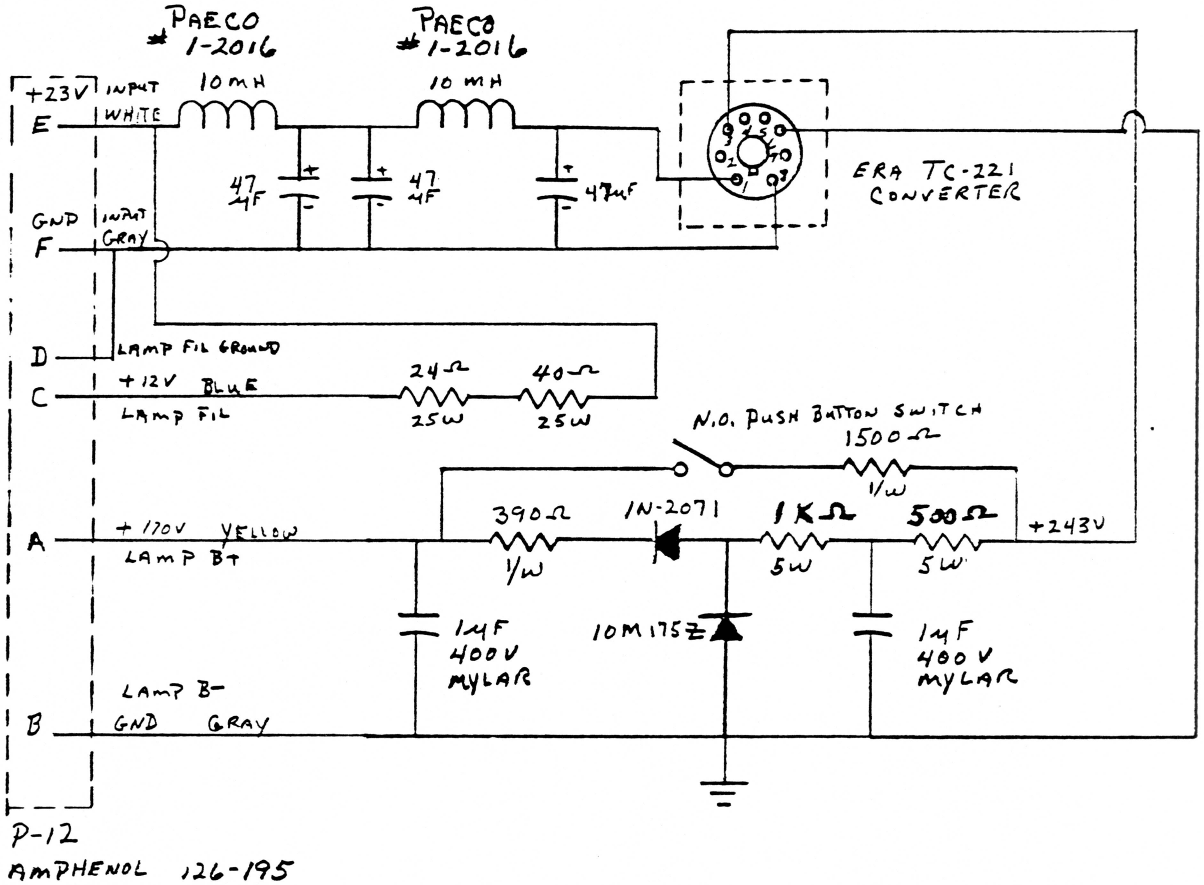
→ +23V IN

→ +23V RTN

→ F

→ PHOTOCELL OUT

X4700

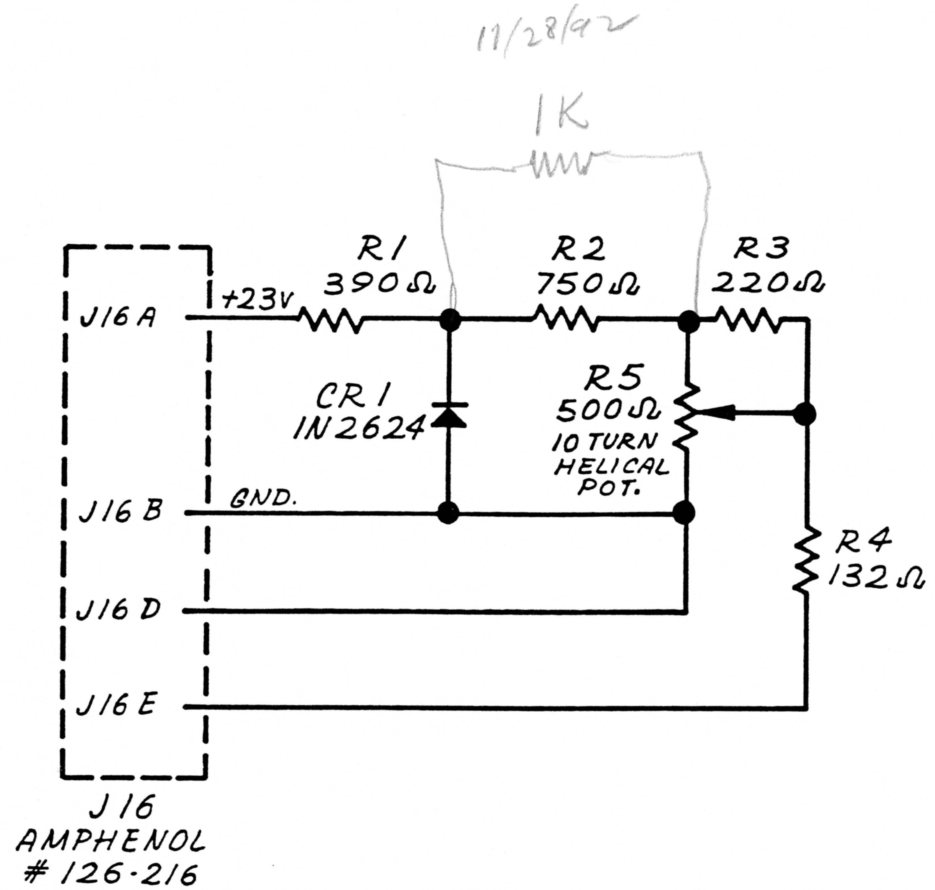


DC-DC CONVERTER SCHEMATIC
SK-27131

DASH NO.	TYPE OR MODEL	NEXT ASSEMBLY	REQ	PART NUMBER	MATERIAL	ITE
	V-4700A					

A SK-27/32 A

DO NOT SCALE DRAWING



CHANGED FROM	
	R2 WAS 820Ω
	R3 WAS 200Ω
	R4 WAS 100Ω
	THIS REVISION APPLIES TO X-4700,#3
	& SUBSEQUENT UNITS
NUM	
ECO	
DFT	W.W. HANDLEY
CHK	
DATE	3/20/62
REV	A

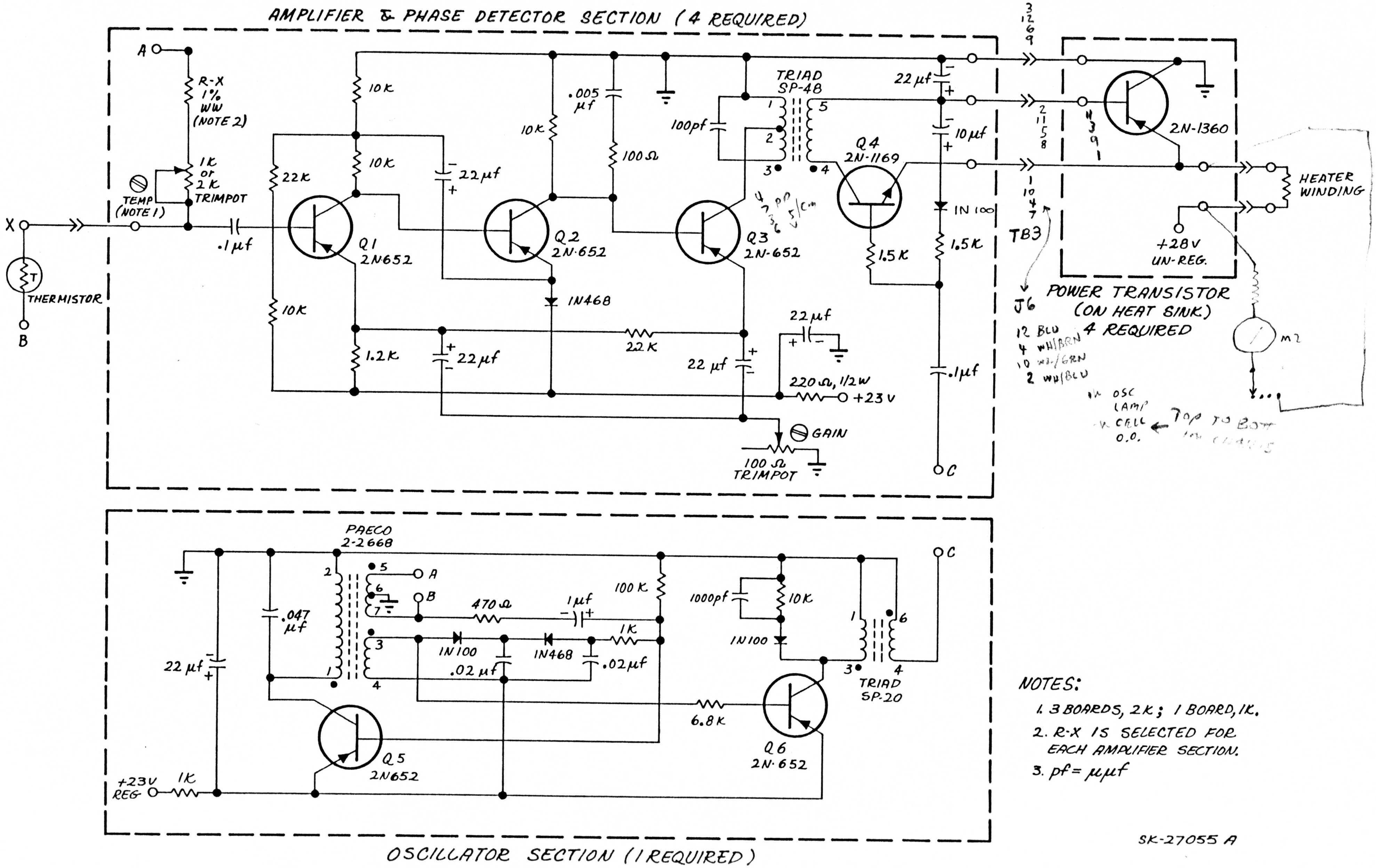
DRAWN	DATE	UNLESS OTHERWISE SPECIFIED: FRAC ± DEC ± ANG ± FIN. ✓		
W.W. HANDLEY	3/20/62			
CHECKED	DATE	APPROVED	DATE	SCALE

FIELD BIAS SCHEMATIC

FINISH OR MFG SPEC	DIVISION	CLASS	CODE

VARIAN associates
PALO ALTO 2. CALIFORNIA

SIZE	DRAWING NO.	REV
A	SK-27/32	A



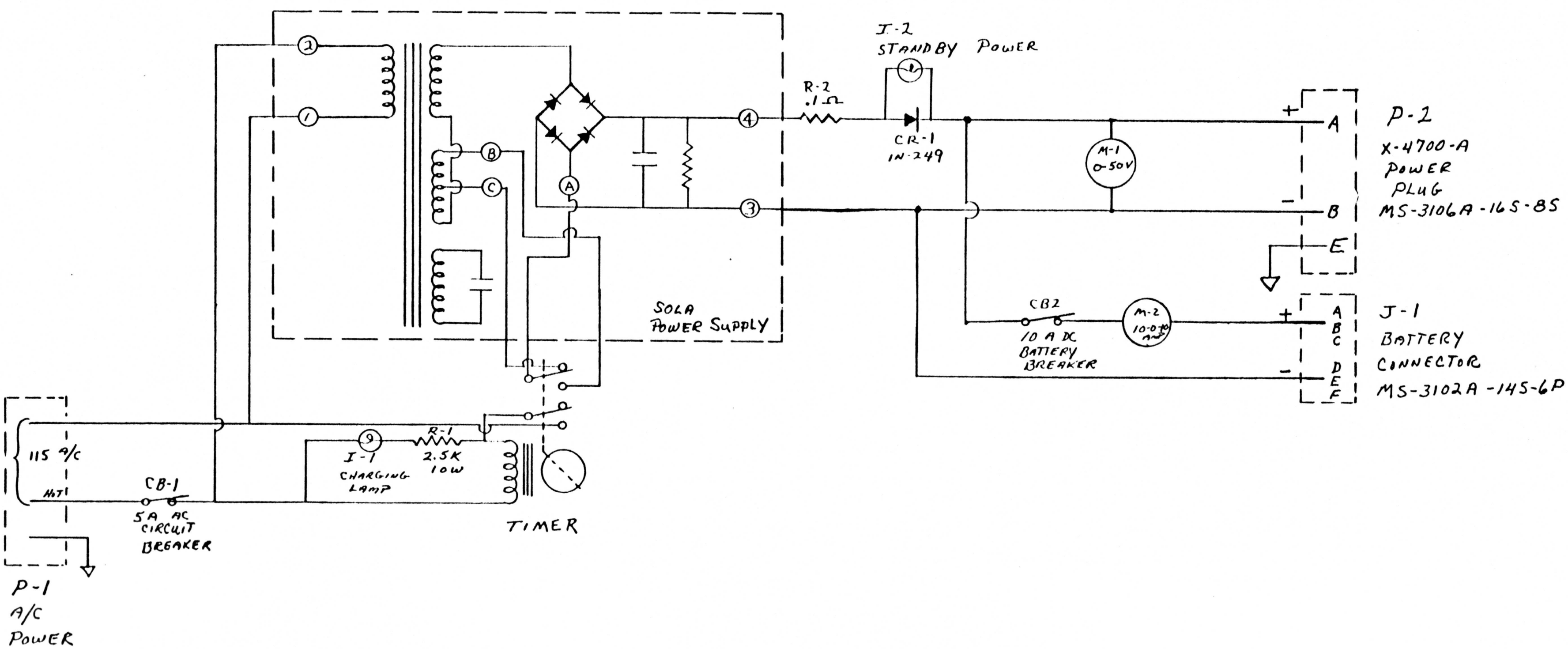
NOTES:

1. 3 BOARDS, 2K; 1 BOARD, 1K.
2. R-X IS SELECTED FOR EACH AMPLIFIER SECTION.
3. pf = μμf

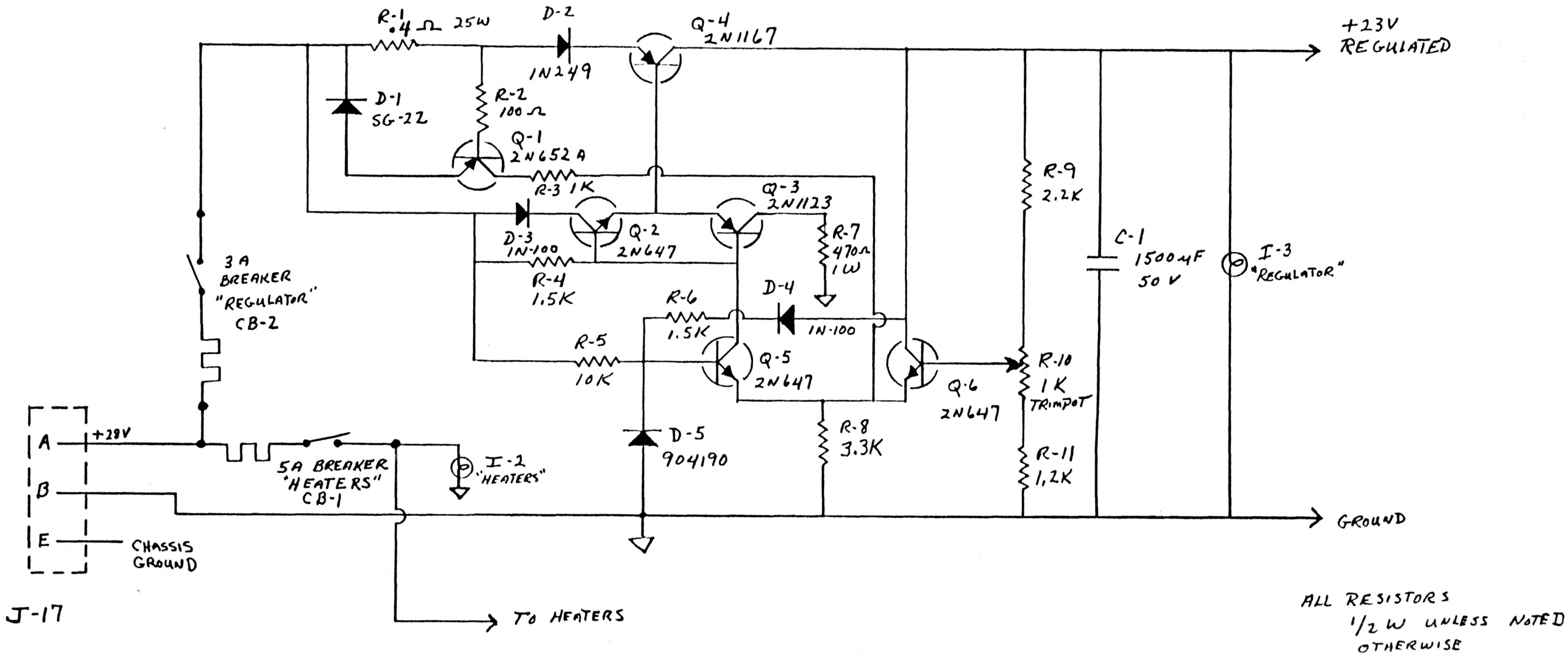
SK-27055 A

TEMPERATURE CONTROLLER SCHEMATIC

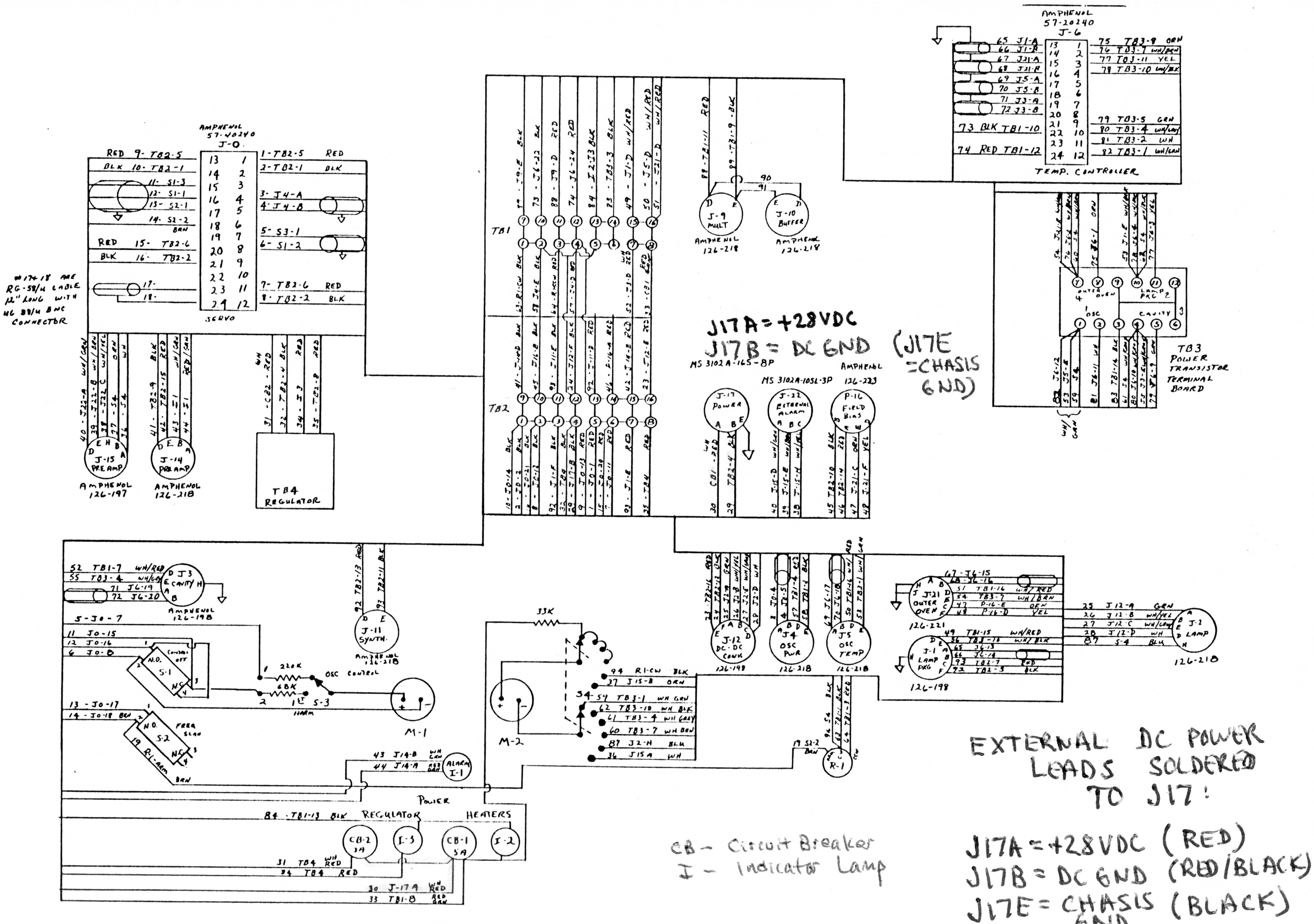
SK-27055 A



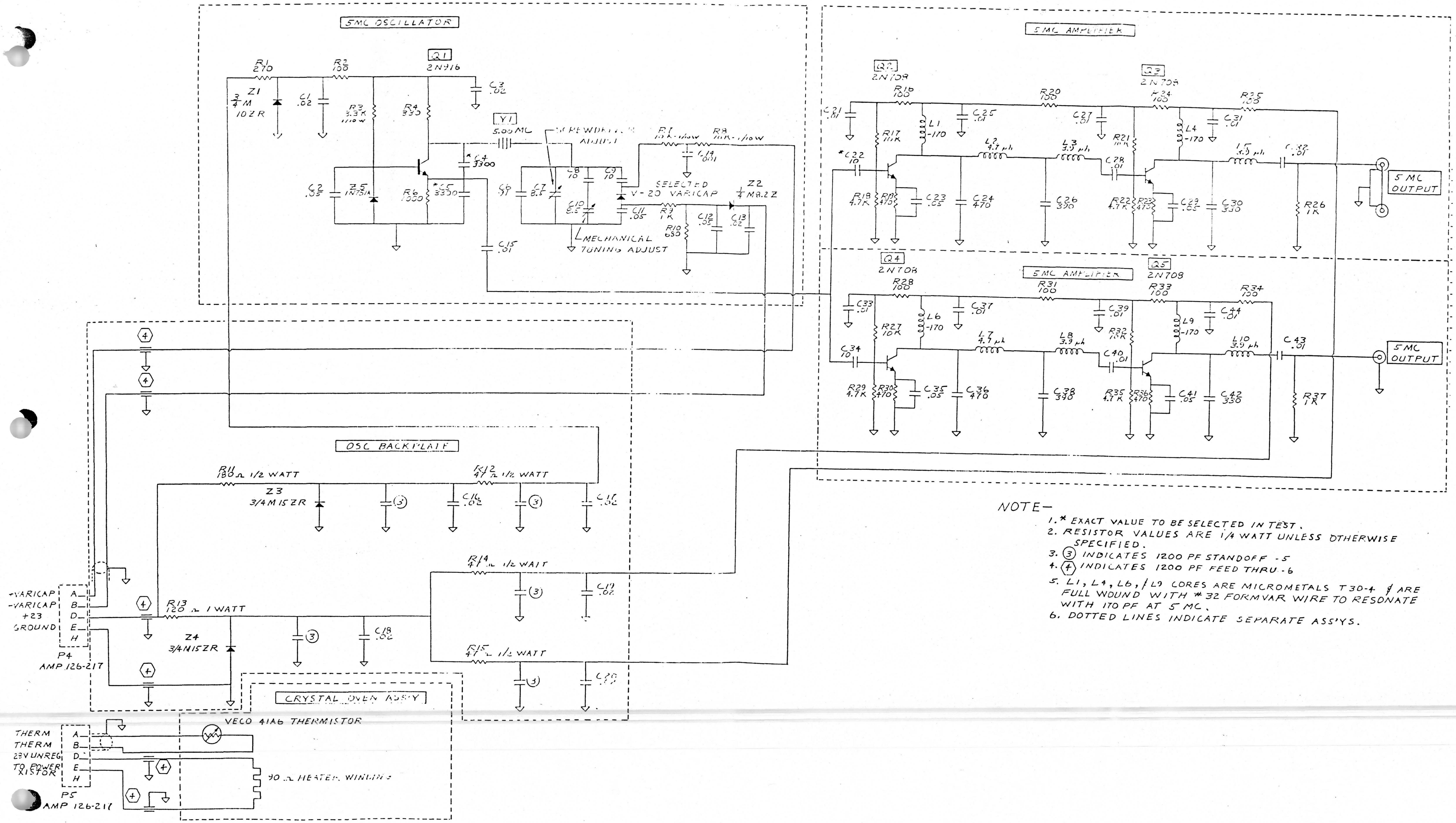
V-4760 POWER SUPPLY SCHEMATIC
SK-27133A



VOLTAGE REGULATOR SCHEMATIC
SK-27152



V-4700A CABLING DIAGRAM
SK-27135

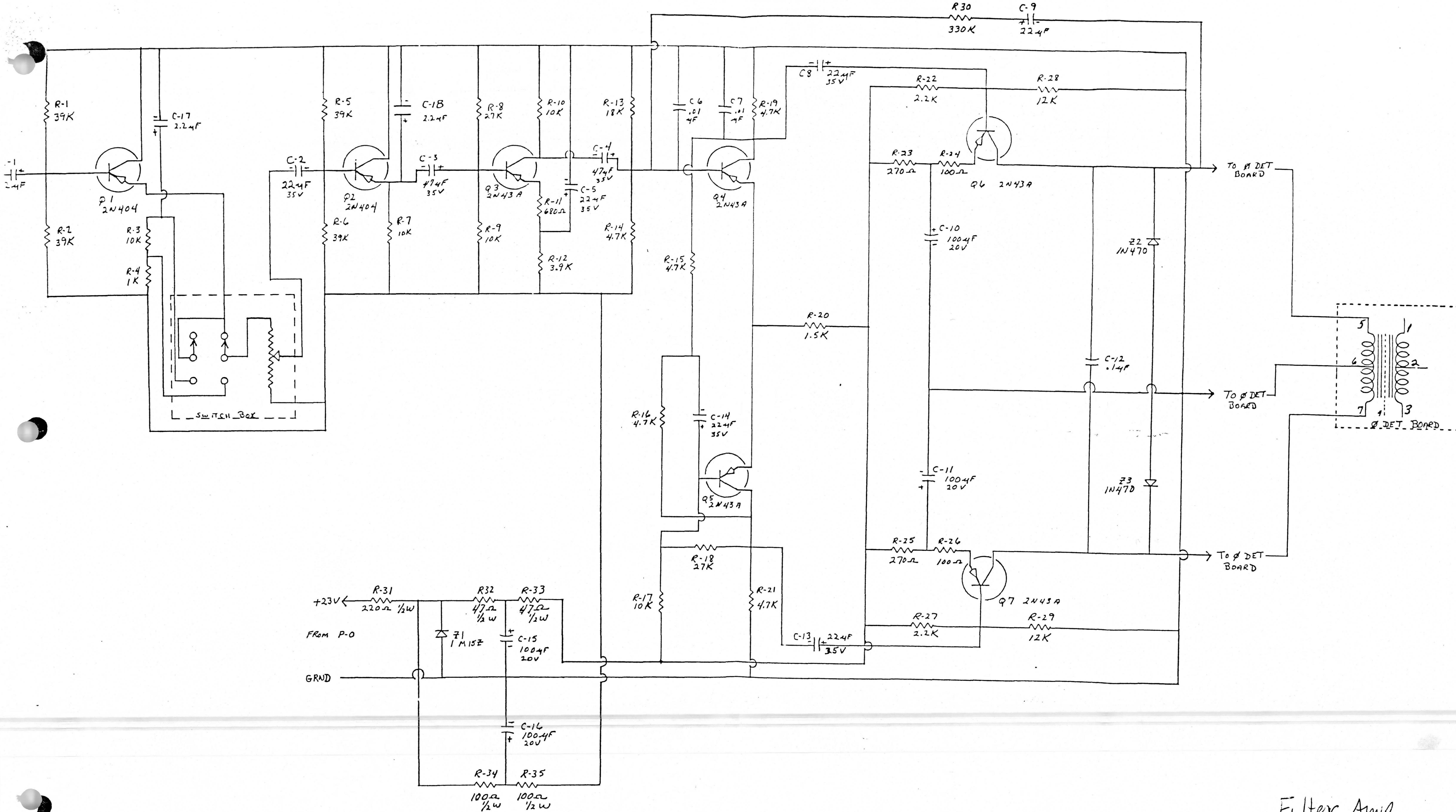


NOTE–

1. * EXACT VALUE TO BE SELECTED IN TEST.
2. RESISTOR VALUES ARE 1/4 WATT UNLESS OTHERWISE SPECIFIED.
3. (3) INDICATES 1200 PF STANDOFF -5
4. (4) INDICATES 1200 PF FEED THRU -6
5. L1, L4, L6, & L9 CORES ARE MICROMETALS T30-4 & ARE FULL WOUND WITH #32 FORMVAR WIRE TO RESONATE WITH 170 PF AT 5 MC.
6. DOTTED LINES INDICATE SEPARATE ASS'YS.

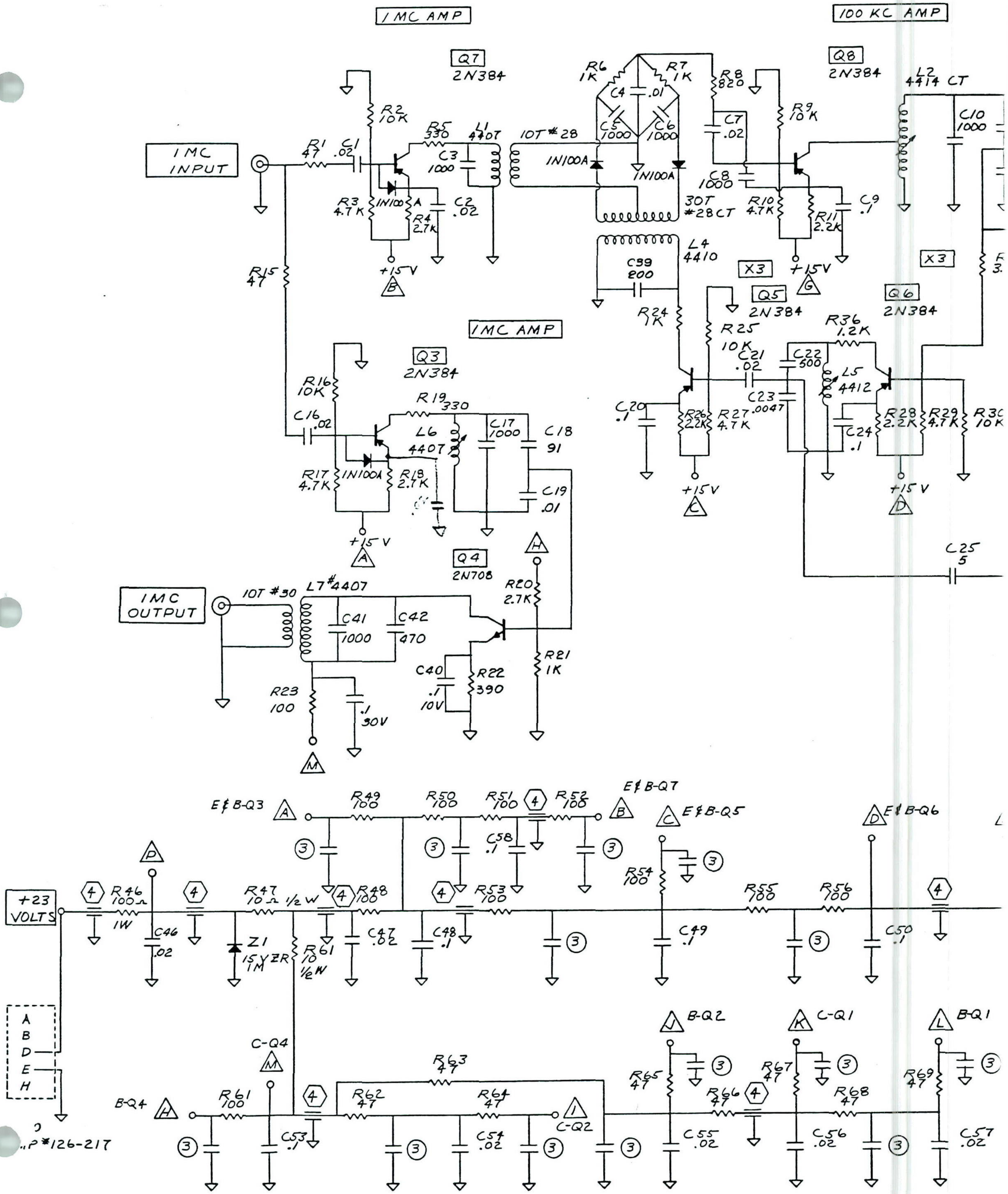
5 MC OSCILLATOR SCHEMATIC

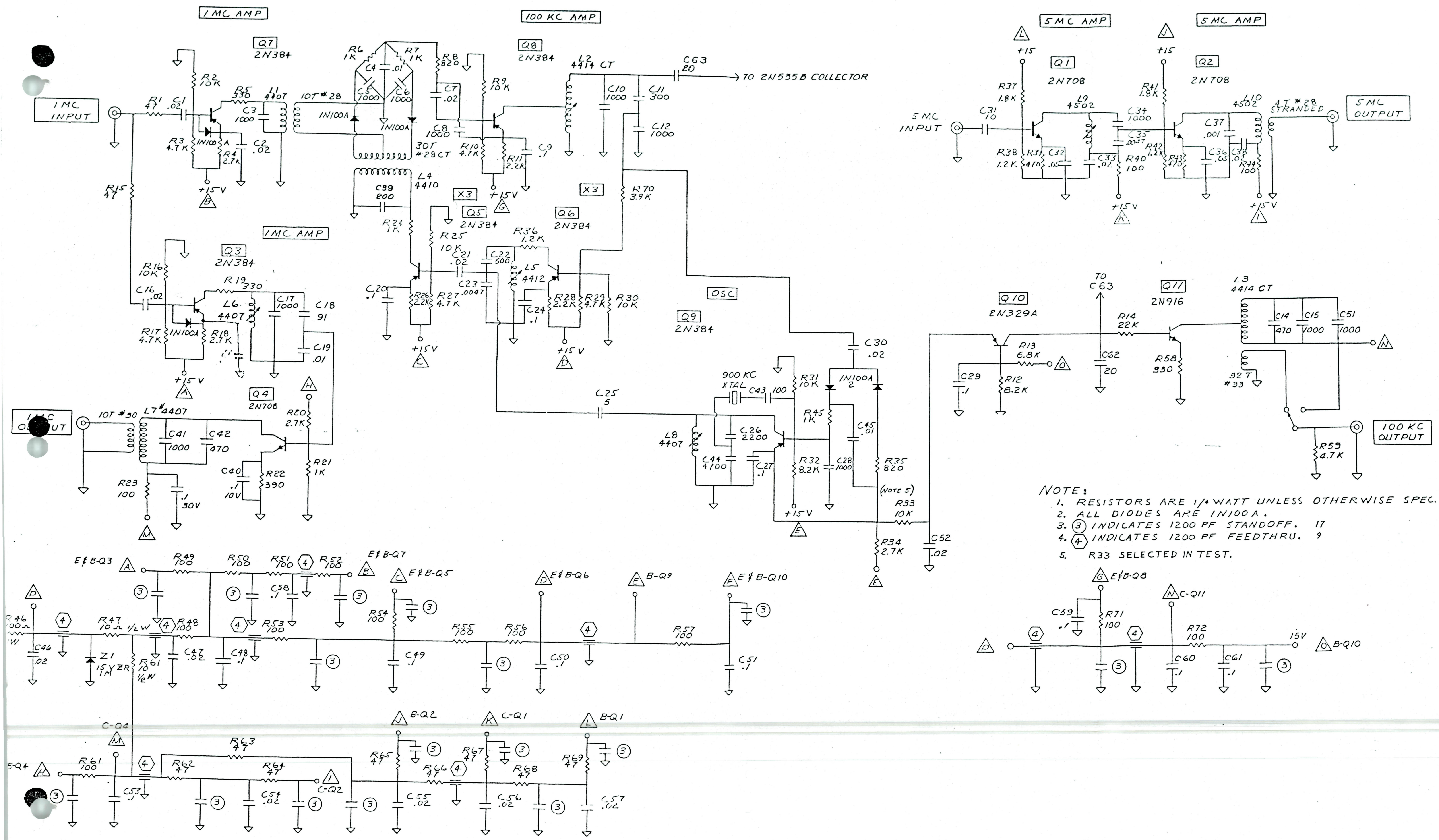
SK-27154



Filter Amp

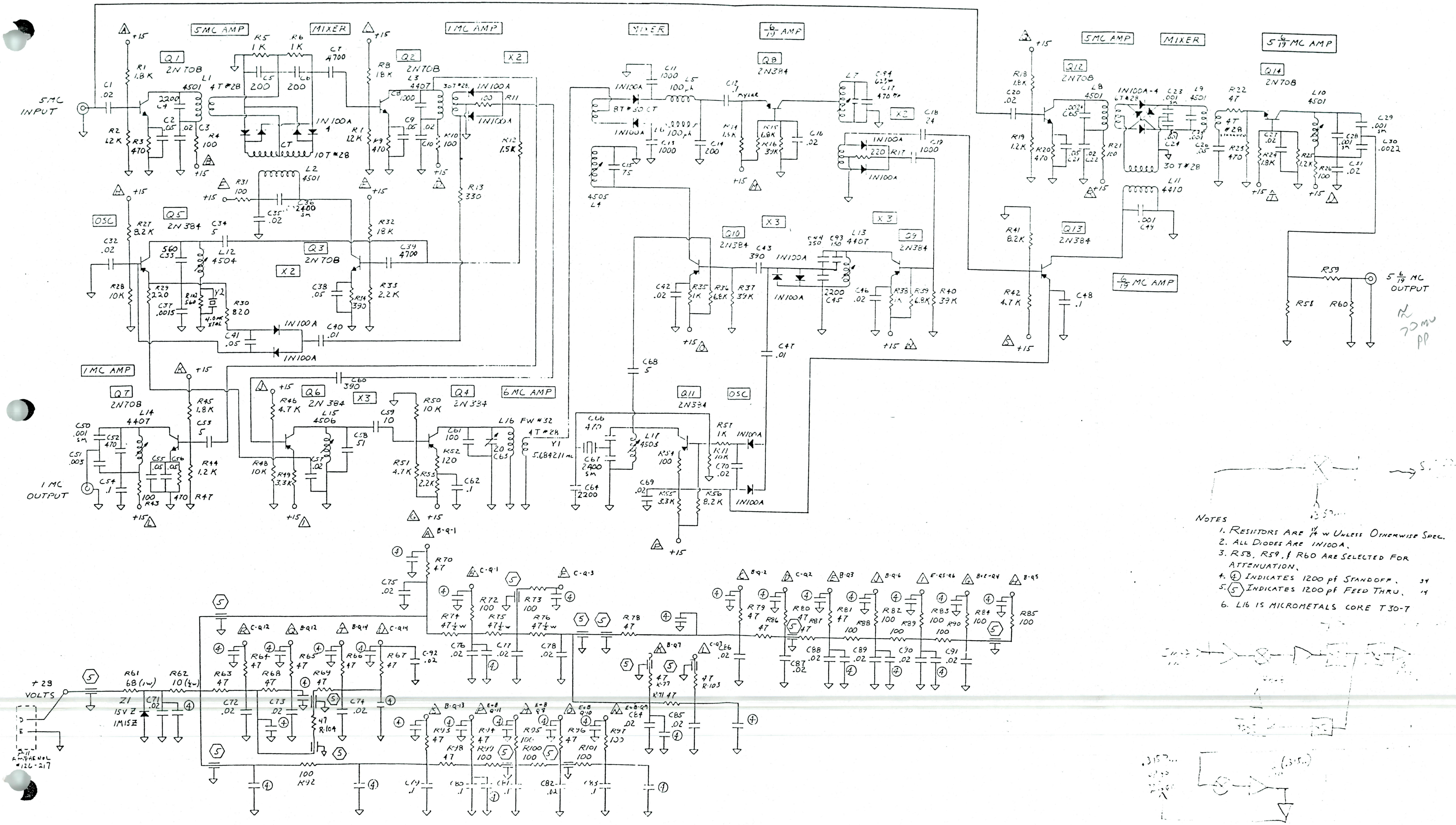
FILTER AMPLIFIER SCHEMATIC
SK-26940


1MC AMP
100 KC AMP
Q7
2N384
Q8
2N384
1MC INPUT
R1 47
C1 .02
R2 10K
R5 330
L1 4407
C3 1000
C2 .02
R3 4.7K
1N100
A
R4 2.7K
+15V
B
10T #28
R6 1K
R7 1K
C4 .01
C5 1000
C6 1000
1N100A
1N100A
30T #28CT
R8 820
C7 .02
C8 1000
R9 10K
R10 4.7K
R11 2.2K
C9 .1
L2 4414 CT
C10 1000
G
L4 4410
C39 200
X3
X3
R15 47
1MC AMP
Q3
2N384
R16 10K
C16 .02
R19 330
L6 4407
C17 1000
C18 91
C19 .01
R17 4.7K
1N100A
R18 2.7K
Q5
2N384
Q6
2N384
R24 1K
R25 10K
C21 .02
C22 500
C23 .0047
R36 1.2K
L5 4412
C20 .1
R26 2.2K
R27 4.7K
C24 .1
R28 2.2K
R29 4.7K
R30 10K
C
D
C25 5
H
Q4
2N708
R20 2.7K
1MC OUTPUT
10T #30
L7 #4407
C41 1000
C42 470
C40 .1 10V
R22 390
R21 1K
R23 100
.1 30V
M
E & B-Q3
R49 100
R50 100
R51 100
R52 100
E & B-Q7
E & B-Q5
E & B-Q6
C58 .1
P
+23 VOLTS
R46 100Ω 1W
C46 .02
R47 10Ω 1/2W
R48 100
R53 100
Z1 15V ZR 1M
R61 10 1/2W
C47 .02
C48 .1
R54 100
C49 .1
R55 100
R56 100
C50 .1
A
B
D
E
H
C-Q4
B-Q2
C-Q1
B-Q1
J
K
L
R63 47
R65 47
R67 47
R69 47
B-Q4
R61 100
R62 47
R64 47
C-Q2
R66 47
R68 47
C53 .1
C54 .02
C55 .02
C56 .02
C57 .02
P*126-217



BUFFER BOX SCHEMATIC FOLDOUT

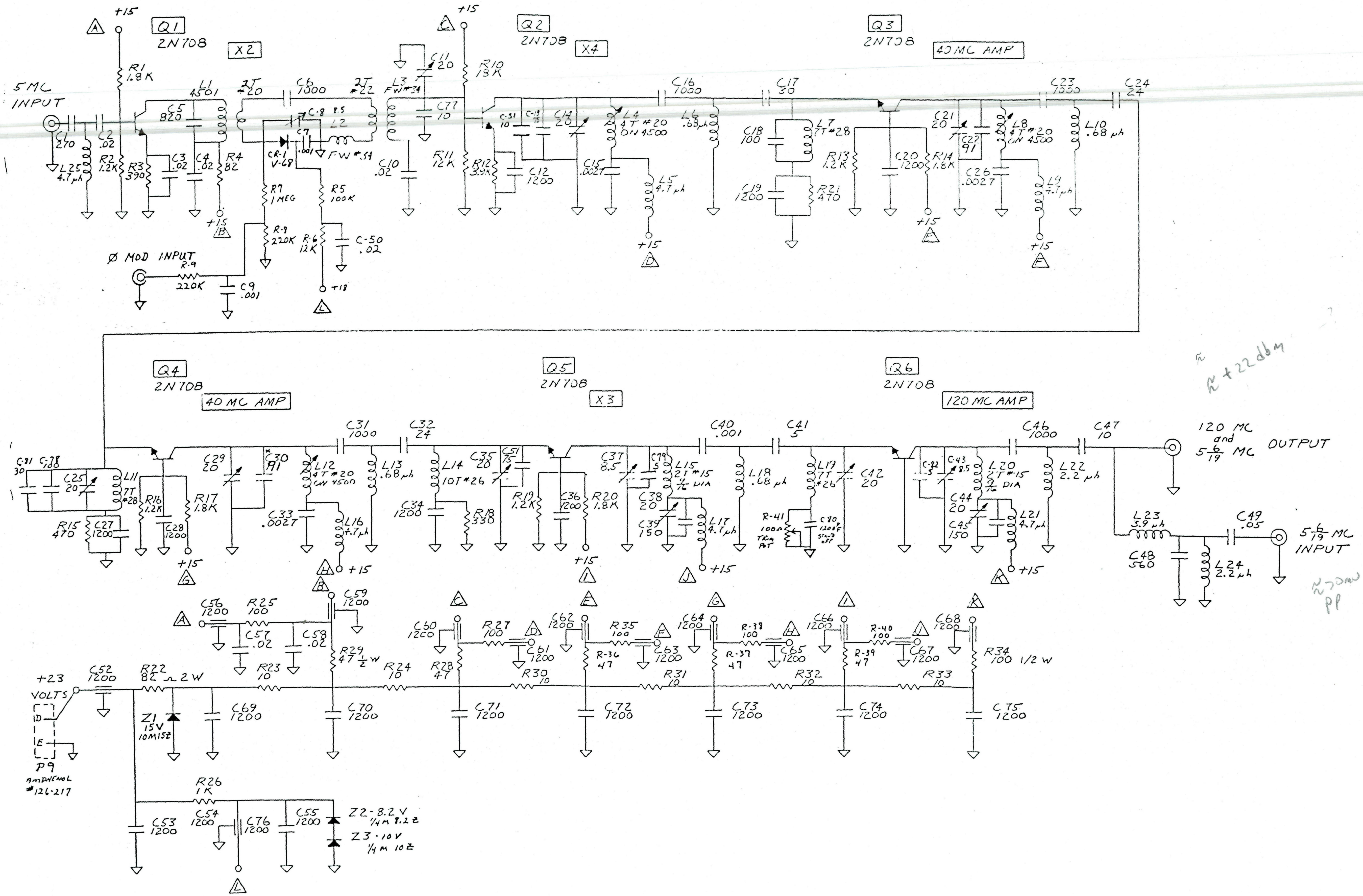
5 MC OUTPUT (SK-27153A)



NOTES

1. RESISTORS ARE 1/4 W UNLESS OTHERWISE SPEC.
2. ALL DIODES ARE 1N100A.
3. R58, R59, & R60 ARE SELECTED FOR ATTENUATION.
4. (4) INDICATES 1200 pf STANDOFF. 34
5. (5) INDICATES 1200 pf FEED THRU. 14
6. L16 IS MICROMETALS CORE T30-7

SYNTHESIZER SCHEMATIC
SK-27021



MULTIPLIER SCHEMATIC
SK-27032